Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN

JOURNAL OF SCIENCE.

EDITORS
JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS
PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

PROFESSORS H. A. NEWTON AND A. E. VERRILL, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XLII.—[WHOLE NUMBER, CXLII.]

No. 252.—DECEMBER, 1891.

WITH PLATE XVI.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1891.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

HOLIDAY PRESENTS.

The systematic collections that we put up are very attractive as well as instructive. The hard wood boxes add much to the desirability of the collections for presents to young people. Many a child might have its tastes turned to natural history by even the 50c. collection which is very pretty.

NUMBER OF SPECIMENS.	25 in box.	50 in box.	100 in box.	100	200	300
Crystals and fragments, ¾ in	$ 50	$1 00	$2 00	$1 00	$2 00	$4 00
Student's size, larger, 1½ x 1½ in	1 50	3 00	6 00	5 00	10 00	20 00
Amateur's size, 2¾ x 2 in				10 00	20 00	45 00
High School, or Academy size, 2½ x 3½ in., Shelf Specimens				25 00	50 00	125 00
College size, 3½ x 6 in., Shelf Specimens				50 00	100 00	250 00

Petrified wood (described last month), **garnets** from Alaska, Salida and many other localities, **opals** from Mexico and elsewhere and many beautiful species for presents for collectors can be supplied.

Meteoric Iron from Cañon Diablo in complete pieces from 25c. upward. This is the cheapest and most interesting meteoric iron ever sold.

Matlockites, Phosgenites from England. We have received from the collection of a gentleman recently deceased at the locality the finest specimens ever offered for sale in this country. They are priced lower than the price paid the men at the locality. **Anglesites** from the same locality and some yellow from Fresno, Utah, just determined.

Chrysoberyl. Fine twin crystals on the gangue from a new locality in Maine, 25c. to $5.00.

Diaspore Margarite and **Corundophyllite** from Chester, Mass., from 10c. to $5.00. Many other new arrivals.

SCIENTIFIC BOOKS.

Some Rare and Valuable Books from the largest stock of Scientific and Medical books in the World. Send for catalogues specifying in what branch you are interested.

Holbrook's Herpetology. Very rare. $50.00.
Barton's Medical Botany. $10.00.
Says. Entomology, edited by LeConte, 2 vols. 64 plates plain, $5.00, colored edition. $8 50.
Agassiz. Echinodermes, 2 vols. 63 plates, 4to. and folio. $7.50.
Bureau of Ethnology, 6 vols. Colored plates, 4to. 1879 to 1885. $12.50.
Cuvier. Animal Kingdom, edited by Griffith, Pidgeon, et al., 16 vols. 799 plates. $20.00.
Pacific R. R. Survey, 13 vols. $12.50.
American Journal of Science and Arts, 138 vols. $275.00.
Hayden, U. S. Geological Survey. Monographs, 12 vols., 4to. $27.50.
Wheeler's U. S. Geological Survey, 8 vols., 4to. $20.00.
U. S. Geological Surveys. Annual Reports, 10 vols., 4to. $12.50.
Baird, Cassin & Laurence. Birds of North America, 2 vols. $5.00.
Holbrook, North American Herpetology, 4 vols. $75.00.
Agassiz. Contributions to Natural History of U. S., 4 vols., 4to. $25.00.
Popular Science Monthly. Complete set to 1890. $35.00.
Humphreys & Abbot. Physics and Hydraulics of the Mississippi, 20 plates, 4to. $3.50.
American Naturalist. Complete set to July, 1891. $60.00.
Elliott, Botany of South Carolina and Georgia, 2 vols., 1824. $7.50.
Nature. Complete set to 1890. $50.00.
Pennsylvania Geological Survey, 100 vols. $35.00.
Baird, Brewer & Ridgway. North American Birds, 3 vols., 64 plates, 593 illustrations, 4to, 1874. $20.00.
Bischoff, Chemical and Physical Geology, 3 vols. 1854–1859. $10.00.
Lowe and Howard. Beautiful Leaved Plants. 60 colored plates, 1872. $5.00.
Sowerby, Recent and Fossil Shells. 264 plates, 1825. $15.00.
Torrey, Botany of New York. 161 plates, 4to. $7.50.
Shaw & Stephens. Zoology, 28 vols. 1200 plates, fine calf. $20.00.
Hayden, Geological Atlas of Colorado. Folio, 1878. $3.50.
King, Exploration of 40th Parallel, 9 vols, 4to, and folio complete. $40.00.
Pursh, Plants of North America. 24 colored plates. $10.00.
Coffin, Winds of the Globe, 4to. $5.00.
Lowe, British and Exotic Ferns, 8 vols., 479 colored plates, 1880. $20.00.

A. E. FOOTE,
4116 Elm avenue, Philadelphia, Pa., U. S. A.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XLVII.—*On Percival's map of the Jura-Trias trap-belts of Central Connecticut, with observations on the upturning, or mountain-making disturbance, of the Formation;* by JAMES D. DANA. With a map. Plate XVI.

IN my paper on the features of non-volcanic igneous ejections as illustrated in the Four "Rocks" of the New Haven region at page 79 of this volume, the resemblances in general structure and system of arrangement between the West Rock trap-ridge and the other trap-ridges of the Jura-Trias in the Connecticut valley are referred to as evidence of oneness in method of origin; and also of oneness in time of origin, whether before or after the upturning of the sandstone, the great mountain-making event of the valley. This evidence—now contested though formerly considered conclusive—cannot be fully appreciated without a knowledge of the general arrangement of the trap-belts of the valley. Happily, we have an excellent map of these belts in Percival's geological chart, published in his Report of 1842 on the Geology of the State of Connecticut.*

* An octavo volume of 496 pages, with a folded geological chart of the State.

James G. Percival, born and brought up in the township of Berlin, southwest of Hartford, was early familiar with all the intricacies of that knotty region of trap-belts. He became a great scholar in all the learning of the day—an excellent mathematician, a professor of chemistry in 1824, a learned linguist and philologist, one of the best of geographers; and in all departments he was an acute and thorough student and observer. Along with this he had a wonderfully good eye for topography, and a memory which retained all the facts that ever entered it. Nearly all the money he received went for the purchase of books, and he thus acquired a very valuable library at the expense of poverty to himself. At

The Map: some of the Features of the area, and facts connected with its Southern termination.

As Percival's Report is little known among geologists I introduce a photo-engraved copy of the middle portion of his chart, which includes the larger part of the Jura-Trias area, along with borders of the eastern and western metamorphic regions of the State. It makes Plate XVI.

The Jura-Trias area, or that of the Connecticut valley sandstone, is the colored portion. The length from the Sound to the northern limit, 3 miles north of Hartford, is about 37½ miles. It contains all of the more complicated portion of the trap-region of Connecticut, the part omitted having only the continuation of the two western belts and another smaller on the western margin of the area.

The narrow linear areas on the map are the trap-belts. They include, according to Percival, simple trap-dikes and dikes with outflows between layers of sandstone. The breaks in the trap-belt of a range generally correspond to actual intervals in the extrusions of trap. But in some cases, as in the body of Mt. Carmel, they indicate only abrupt depressions in the ridge, Percival appearing to regard them as a consequence of partial interruptions in the outflow; and in the southern end of West Rock, where the bay of sandstone just north (Plate VI) evidently suggested a similar supposition.

About New Haven the figures 1, 2, 3, 4, mark successively East Rock, Mill Rock, Pine Rock and the West Rock Ridge. The long southern part of the latter is lettered W S I, and the northern W S I I. North of North Haven at 6 is Mt. Carmel. In the northern part of the town of Meriden are the "Hanging Hills"; and 3, 4, 5, 6, 7, 8, 9, and others beyond are parts of the longest and most elevated trap-range of the valley; it continues to Mt. Tom in Massachusetts, nearly 56 miles, and has a height of 996 feet at its southern end according to Guyot's barometric observations.

To the east of New Haven and New Haven Bay, in East Haven, the bow-shaped trap-ridge, E I, is the Saltonstall

his death it was sold for $20,000. Such was the man that made the remarkable survey of the trap-belts of Connecticut. He received but small pay from the State, and at last had to content himself with a very insufficient sum for the publication of his Report—"not exceeding $1,500, for printing and superintending." The Report is therefore but an abstract, as he says in his Preface, of what with more generous treatment he would have published.

His geological science was not altogether that of the present day; for he believed that the crystalline formations were segregations out of a world-wide magma: but he still, as he says, recorded in his note-book more than 8,000 dips and strikes, realizing their value in investigation far better than many a recent student of such rocks. It is greatly to be regretted that a full Report was not published.

Percival was born in 1795 and died in 1856.

ridge (Pond ridge, of Percival) on the west side of Saltonstall Lake. To the north of this ridge, and a little to the eastward, is another bow-shaped ridge, the Totoket; and the line of these two ridges is continued northward by other high trap-ridges, extending along the western borders of the townships of Durham and Middletown and beyond toward Hartford.

In the metamorphic region, outside of the Jura-Trias, there are two dikes, one on the east, and another on the west. They are referred by Percival rightly to the same system as those within the area. That on the west is the "Buttress Dike" in its course through Woodbridge and Orange, lettered W. 1. The eastern one commences in Branford and is continued through North Branford, where it is lettered 3 E. 1., and northeastward, as mapped by Percival, to the Massachusetts line.

The large river in the northeast corner of the map is the Connecticut. At Hartford its course becomes changed from south-by-west to south; and at Middletown it leaves the Jura-Trias area and goes off southeastward to the Sound, the waters having been forced from their former course by the barrier to the west made of belts of trap and adjoining hard sandstone—an event which took place whenever this trap region was raised above the sea-level. The valley lying to the west of the Mt. Tom trap-range contains to the north the large bend of the Farmington River; the left side of the bend received waters from the northwest, the right continues the flow northeastward to the Connecticut. South of this there are the head-waters of the Quinnipiac, and still farther south, Neck River, the stream also called Mill River.

The southern end of the area, as is shown on the map, narrows rather abruptly, owing mainly to the bending westward of the eastern side. While the width is eighteen miles in the latitude of Middletown, it is hardly two at the entrance to New Haven Bay, the southern end of the Jura-Trias estuary. The granitoid gneiss of the eastern shore and of Light House Ledge extends to within two miles of the slaty rocks (chloritic hydromica schist) of the western cape, or Savin Rock;* and as the depth off the latter cape is but a few feet and over sands for a long distance out, the actual width of the interval may not be more than a mile and a half. The outline on the east is followed closely by the easternmost trap-dike, showing, apparently, that the narrowing is a fundamental feature of the

* The granite-and gneiss of the eastern Cape are probably Archæan, and the hydromica schist of the western side with the feebly crystalline limestone which occurs in it, and with other schists to the west, may be early Paleozoic.

area, and not one due to a subsequent uplifting of the coast-region and its denudation. This narrow channel at the end is the more remarkable in view of the fact that only five miles north of the outcropping granite of the shore, the sandstone, —as the recent condition of the boring at the Winchester Repeating Arms Factory shows—extends to a depth below the sea-level of at least 3,100 feet. The metamorphic rocks of the hills to the west are only two miles distant, and hence that side of the trough has a mean pitch of 1 : 3½, or about 17½ degrees, but much larger than this, probably in the western or outer of the two miles, and smaller in the inner. The southern extremity of the Jura-Trias trough or geosyncline has, hence, something of the shape of the prow end of a boat.

These facts seem to prove that the Jura-Trias trough, or at least its lower 3,100 feet, did not extend out into the Sound but had its termination in what is now New Haven Bay.

For explanations of the lettering on Percival's map and other details, reference must be had to his Geological Report. The scale of the map is nine-tenths of an inch to five miles.

The uplifts, whether before or after the trap ejections.

Is the West Rock trap-range in which the uplifting preceded beyond question the eruption, typical for all the north-and-south trap-ranges? The form of the trap-belt on the map is strikingly like that of other trap-ranges in the valley, in the little width of its outcrop, in the composite character of the belt, in its hooked extremity, in the curvature and overlapping feature of the parts, and in its gradual disappearance seventeen miles to the north just west of where another greater range—the Mt. Tom Range begins. The fact that this western range was erupted after the upturning of the sandstone affords hence some reason for suspecting that this was true also of the rest of the trap in the system of ridges.

In East Haven, east of New Haven, the first trap-ridge west of Saltonstall Lake afforded, at its southern end, the section on page 104, proving that this belt also, like that of West Rock, was erupted after the upturning of the sandstone. This ridge is only 500 yards west of the Saltonstall Ridge, and it may be reasonably believed that the bow-shaped ridge was also an outflow after the upturning. This conclusion is sustained by the further fact that the third example of trap overlying upturned sandstone mentioned on page 105, stands directly to the east and only 3000 yards away. Moreover Dr. E. O. Hovey, in his paper already referred to, makes the trap of Saltonstall ridge intrusive; and the conclusion, according to my own examination with him of his facts, I believe to be right.

Again, Dr. Hovey has proved that the first trap-belt *east* of the Saltonstall belt, just across the lake, is a dike. It is shown by the hard-baked condition of the sandstone on its east side. He infers also that it was subsequent in origin to the Saltonstall belt, since the overlying sandstone contains stones of vesicular trap which were derived with little doubt, like those of the Jura-Trias bowlder-conglomerate south of the northeastern extremity, from this northeastern extremity. The position of the hills of bowlder-conglomerate is shown on the map (Plate XVI).

Further the bow-shaped form of Saltonstall ridge is repeated almost exactly in the larger ridge next north, the Totoket, and hence whatever is true of one as to origin is pretty certain to be true of the other. And what then of the other ridges farther north in the same line?

We note also that these bow-like shapes, in the trap, with the dip of the associated sandstone on the east side of each—as observed by Professor Davis, and later for Saltonstall ridge by Dr. Hovey—toward the center of the arc, is not the form or condition to be looked for in regions of monoclinal uplifts. The dip is nearly centroclinal not monoclinal.

The map enables the reader to observe that the facts here cited favoring ejection *after* the upturning, that is, after the great mountain-making event of the valley, are from the whole width of the southern end of the Jura-Trias area; and it is also seen that from this end northward there are suggestive facts bearing in the same direction. Still they are not complete demonstration that this is true for the northern part of the area. We have to leave the question here until other long east-and-west sections of north and-south trap ridges as complete as that of West Rock have been reported upon.

In the account of the East Rock ridge (page 98 of this volume) the separation of the Snake Rock trap-mass from that of East Rock and Indian Head, and the bow-like shape of the latter with centroclinal dip in this southeastern part, have been attributed to the caving in of the hanging wall of the eastward-dipping fissure that supplied the lava. It is worthy of consideration whether the south end of the Totoket bow and the northern of the Saltonstall line may not have had a similar origin.

Character of the Mountain uplifts made at or near the close of the Jura-Trias period.

Like the post-Carboniferous mountain-uplifts, the parallel series made at the close of the Jura-Trias were commenced by the accumulation of sediments in gradually deepening depressions of the earth's crust, or geosynclines; but while the era of deposition in the former ended in displacements producing great flexures of the accumulated formations besides profound faults,

that of the latter ended in producing monoclinal uplifts, and also, it is believed, great faults. Further, while the post-Carboniferous uplifts of the Atlantic border include three individual mountain-ranges: (1) That of the Appalachian area from Alabama to the Catskills, 1500 miles long; (2) That extending from Newfoundland southwestward through Nova Scotia, and probably to Rhode Island, in all 1000 miles long, and that of the Gaspé-Worcester range,* the post-Jura-Trias system embraced eight or more individual ranges, of cotemporaneous origin, each of the several basins having been independent in its geosyncline and in its uplifts.

Of the two mountain-making epochs, only the latter included, among the events of each mountain-individual, extensive igneous eruptions. Of the ejections in the Connecticut Valley, those of West Rock Ridge and of at least two others in East Haven occurred, in the course, or near the close, of the mountain-making movements. If this proves to be the time of the event in general for the other trap ridges of the valley, then all were a result of, or a sequel to, the movements. But if, as Professor W. M. Davis holds, the trap of most of the ridges originally alternated in sheets with horizontal layers of sandstone and both were uplifted together into monoclines, then the ejections occurred while deposition in the geosyncline was in slow and quiet progress. The decision of the question is, therefore, one of dynamical importance. Professor Davis states that the eruptions had nothing to do with the upturning, and this is true in either case.

Fault planes concerned in the uplift.

The conformity between the general direction of the structure-lines of the Jura-Trias formation and that of the crystalline schists adjoining and the mountain ranges to the west, has long been recognized. The view suggested by Prof. Davis goes beyond this in supposing a conformity also between the dips of the foliation-planes and those of the fault-planes. He says: "A group of inclined slabs compressed by a horizontal force about at right angles to their strike might yield in part by minute internal rearrangement, and in part by slipping on their divisional surfaces, so as to reduce their breadth by standing more nearly vertical, that is, more nearly at right angles to the compressing force. In so doing, the upper surface of the group would be somewhat elevated, and at the same time the bevelled edge of every slab would be tilted over by a tolerably constant angle in one direction, and separated from the neighboring slabs by a dislocation with the uplift on

* This Journal, xxxix, 380, 1890.

the side of the direction of dip. In case the compression varied at different depths, diminishing downwards, a shearing force would be introduced, by which the slabs could be thrown over past the vertical."* Accordingly, his figure represents the sandstone overlying the inclined upper surfaces of the successive slabs or blocks, and as deriving in this way its eastward dip. The fault-planes, it will be understood, are not those of the fissures that supply the trap; for in his view the trap and sandstone were in alternating sheets before the upturning took place. These fault-planes are nowhere open to view, and hence the idea has not been sustained by actual comparisons. It is presented by Prof. Davis simply as an hypothesis for future consideration.

Assuming with him, as we may safely, that the dip of the fault-planes is eastward, I mentioned in my former paper as an exception to the hypothesis, a want of correspondence between the strike of the West Rock dike and other dikes near New Haven and that of the schists within a mile to the westward of West Rock, confining my statement of facts to those of the New Haven region. This objection is not quite apposite, since the comparison is made with the direction of trap-dikes and not with the strike of the sandstone which most nearly represents that of the fault-planes. I now mention other facts bearing on the question. West of the New Haven region, along a line through Orange and Birmingham sixteen miles long, there are five changes between eastward and westward in the dip of the metamorphic schists, and in the course of them there are variations in the dip from horizontal to vertical. The last of the five is a case in which a broad and low anticlinal, consisting of coarse gneiss and mica schist with a bed of crystalline limestone, has the beds for a long distance nearly horizontal. As the mean width of the Jura-Trias area in Connecticut is twenty miles, there is therefore room for equally large variations in the dip of the crystalline schists beneath it. Again, in Berkshire county, Massachusetts, as well as to the north and south, among the metamorphic rocks of the earlier Paleozoic, or Taconic, series, the dips vary from east to west, and from zero to 90 degrees. Such facts, however exceptional, make it necessary to substitute for the expression "planes of foliation," that of planes having the mean or the prevailing, direction of the foliation; for these would be the planes of easiest cleavage in schists of great thickness.

Again, as another modification in the statement of the hypothesis, it appears necessary to make the chief foliation-planes not those of the rocks constituting the upper one, two

* This Journal, xxxii, 349, 1886. See also 7th Annual Report of the Director of the U. S. Geological Survey.

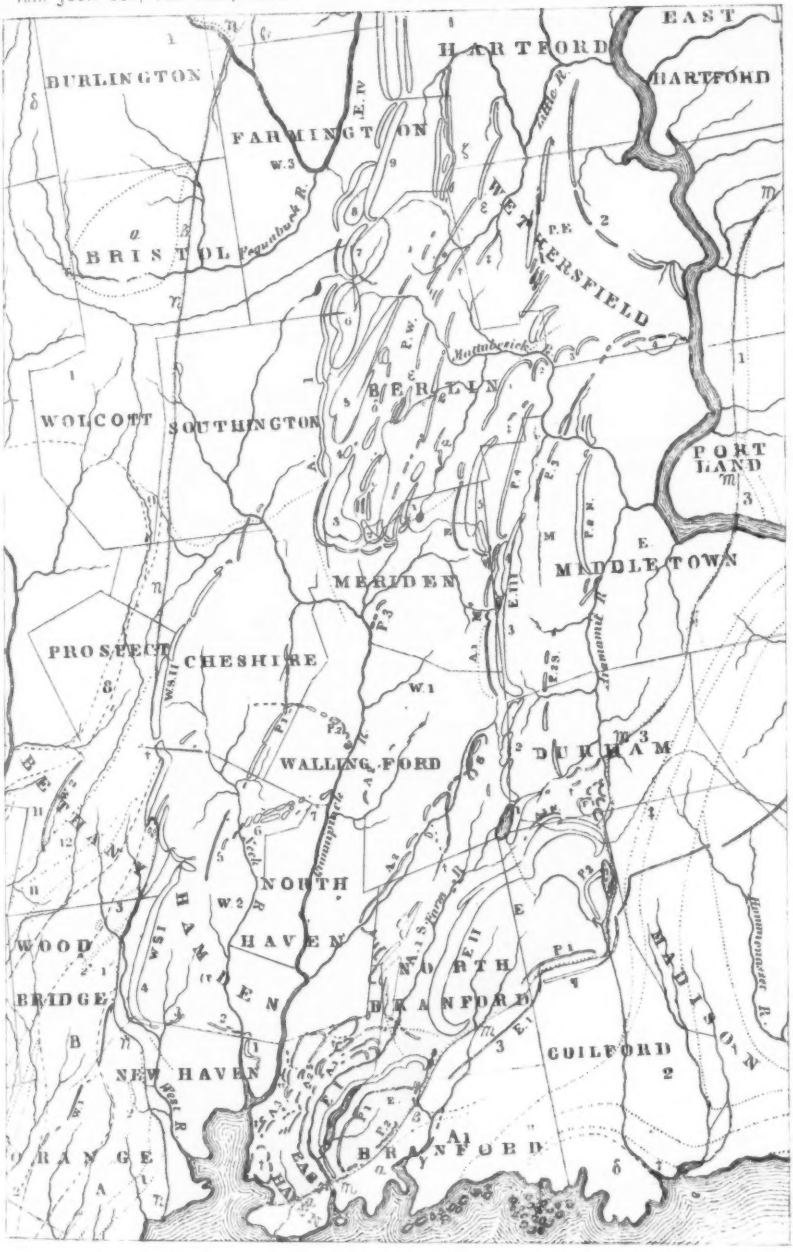
or three miles of the crust, but those below, where Archæan rocks and those subjacent to the Archæan exist. For the fractures were begun below, and in these nether rocks foliation has probably, as a consequence of Archæan pressure or tension, much greater uniformity than in those of the surface. Still the more superficial foliation would have its influence.

Again, the direction of planes of fracture, or of faulting, would have depended largely on the direction of the lateral thrust or pressure in the earth's crust producing the strain, whether normal or oblique, to the plane of easiest cleavage; an idea which, under large extension has been applied by the writer in an explanation of the origin of the courses in the feature-lines of the globe.

The production of an eastward slope in the upper surface of the faulted blocks by compression and molecular transfer, sufficient by the hypothesis to produce the dip in the sandstone, may be questioned; and also the view that the horizontal force concerned would make, in gneiss, and in other rocks equally firm, faulting along foliation-planes of the high eastward dip of 60° to 80°, instead, for the most part, of fractures oblique to these planes. To obtain a dip of 20° in the top-surface of the westernmost slab or block (and the sandstone over it), the displacement a mile down would have to amount to 1800 feet; and to render the westward shove below, to this distance, possible, the compression would have to take much from the thickness of this western block on its western side, and much from the rock next west, a part from each. This would be required whether the other blocks were compressed or not. When done, it would suffice to give the same dip to the top-surface of all the blocks in the series without their compression; but these would also be compressed, and the result would be a large increase eastward of dip—a condition which does not accord with observation.

But suppose the blocks to be so displaced, and pushed up thereby nearly to verticality, or beyond it, then they would have had little or no westward thrust against the sandstone, and accordingly none is appealed to in the statement of the hypothesis. Yet, a pitch of 10° to 25° in the sandstone implies much diminution in the width of the area. If the mean dip is 18° the diminution would be, theoretically, 5 per cent, equivalent to 1 foot in 20; or if 14°, 3 per cent.* The effect should have been manifested in wide longitudinal fissures if this were not prevented by a westward thrust of the sandstone.

* The sandstone in some portions is nearly horizontal, as in the region of the Portland quarries, on its eastern border; and occasionally the dip is westerly. Hence a mean dip of 14° is probably most correct. Small flexures also occur but only locally.


EAST
HARTFORD
HARTFORD
BURLINGTON
FARMINGTON
BRISTOL
WETHERSFIELD
BERLIN
WOLCOTT
SOUTHINGTON
PORT
LAND
MIDDLETOWN
MERIDEN
PROSPECT
CHESHIRE
WALLINGFORD
DURHAM
NORTH
HAVEN
WOOD
BRIDGE
HAMDEN
NORTH
BRANFORD
MADISON
GUILFORD
NEW HAVEN
BRANFORD
RANGE

I pass here to an explanation of the origin of the dip in the sandstone which appears to me to harmonize best with the facts.

Daubrèe's experiments on the effects of lateral pressure, published in his "Géologie Expérimentale" (and briefly presented in my Manual of Geology), have appeared to me to sustain the idea that the great fault-planes of the earth's crust made by lateral pressure must be, as a general rule, very oblique. I have accordingly been led to suppose that the fault planes in the case of the Jury-Trias were examples, and I have referred in my Geology to the dip of nearly 45° in the East Rock dike as having this explanation. Two, three or more such fault-planes, coming up from the depths below and entering the geosyncline, would have among their effects: (1) the narrowing of the arc of the Connecticut valley geanticline; (2) the forcing of the sandstone to accommodate itself to the diminished width through fractures, faults and displacements; (3) the production of earth-shakings of great violence which would have produced other fractures through the 5000 feet or so of sandstone and multitudes of pieces by minor fractures. In this state of the sandstone, the shoving of it to the westward by the westward-and-upward movement of the faulting blocks, would make monoclines with eastward dips, and not flexures, because the blocks into which the formation had been divided were each too short for flexures and the piles of layers would necessarily, under the circumstances, become pushed up one over another. I stated in my former paper that slickensided surfaces of the East Haven sandstone covered blocks of all sizes, from those no larger than the hand to those constituting large sections of a quarry, and also in some places the upper and under surfaces of the layers of sandstone; and this fact accords well with the above explanation of the method of upturning.

If this view is the right one, the westward dip of the Jura-Trias sandstone in New Jersey and to the south was due to fault-planes having a reverse direction from that in the Connecticut valley, that is, a westward dip. The fundamental fact awaiting explanation is not, therefore, the opposite directions of dip in the Connecticut Valley and New Jersey sandstone, but the opposite directions of fault-planes in the subjacent rocks. The two directions of strain appear to have anticlinal relations.

The above explanations, for the reasons already stated, have no reference to the origin of the fissures for the trap ejection. If they are mostly of later date than the upturning, tension may have had much to do with their production. In any case, the old fissure, or part of them, would probably have again been used.

ART. XLVIII.—*The Detection and Determination of Potassium Spectroscopically;* by F. A. GOOCH and T. S. HART.

[Contributions from the Kent Chemical Laboratory of Yale College—X.]

BUNSEN and Kirchhoff originally determined the delicacy of the spectroscopic test for potassium by exploding in a darkened room a mixture of potassium chlorate with milk sugar, and observing the amount of finely divided chloride which it was necessary to diffuse through the given space in order to bring out unmistakably the spectrum of the metal. These investigators were able to state that the presence of no more than $\frac{1}{1000}$ of a milligram of the potassium salt is sufficient to give to the flame the characteristic spectrum of the element. By similar methods, the delicacy of the tests for lithium carbonate and sodium chlorate were shown to be a thousand times and three thousand times as delicate respectively. Practically, the detection of lithium and sodium spectroscopically is extremely easy and satisfactory, the only difficulty being that the exceeding delicacy of the sodium test, and the ubiquitousness of sodium salts often make a decision doubtful as to whether that element is present essentially in the substance under examination, or by accident. With potassium the case is different, and experience shows that, when the test is to be made for very small amounts of potassium, the simple method in vogue for developing the luminosity of lithium and sodium—the dipping of a single loop of platinum wire in the liquid or solid substance, and the placing of the loop in the Bunsen flame—fails, because, as it seems to us, so great a proportion of the material is dispersed before the heat of the flame effects the dissociation of the metal which precedes the production of the spectrum.

We have endeavored to improve the conditions of exposure of the test-substance by making use of more powerful flames and by substituting for the single loop the hollow coils of platinum wire first recommended, so far as has come to our knowledge, by Truchot* in the description of a method for the quantitative determination of lithium. Such coils are easily made by winding the wire somewhat obliquely about a rod of suitable size, pressing the coils close together, and gathering the free ends into a twisted handle. The size of the coils is adjustable without difficulty, so that each coil may be made to hold almost exactly any appropriate amount, and to take up this amount with very little variation in successive fillings, provided only that the precaution be taken in the process of filling to plunge the coil while hot into the liquid, and to keep its axis inclined obliquely to the surface of the liquid

* Compt. Rend., lxxviii, 1022.

while withdrawing it. How closely the capacity of such coils may be adjusted, and how uniformly they may be filled is shown in the figures of the accompanying record.

	I. grm.	II. grm.	III. grm.	IV. grm.	V. grm.	VI. grm.
Weight of filled coil.....	0·1996	0·2780	0·2794	0·2844	0·3572	0·3296
" "	0·1996	0·2780	0·2794	0·2845	0·3571	0·3296
" "	0·1996	0·2780	0·2794	0·2844	0·3572	0·3298
" "	0·1996	0·2780	0·2794	0·2845	0·3571	0·3298
" "	0·1996	0·2781	0·2794	0·2844	0·3571	0·3296
" empty coil....	0·1986	0·2760	0·2764	0·2804	0·3521	0·3100
" contents (mean)	0·0010	0·00202	0·0030	0·00404	0·00504	0·01968

It is plain that we have in these coils simple means of taking up known amounts of material in solution; and by gentle heating the liquid may be evaporated and the solid material left thinly and uniformly spread, not easily detachable, and so in condition to be acted upon with effect when brought to the flame. The evaporation may be conducted with little danger of loss of material by holding the handle of the coil across the flame with the coil proper at a safe distance outside; but we have generally, and preferably, used a hot radiator over which the coils are exposed, the handles resting upon a flat asbestos ring. The burner which we have used in heating the coils before the spectroscope is of the Muencke pattern and gives a powerful flame 3 cm. wide at its base. We have generally adjusted the flame to a height of 20 cm., and have introduced the coil, after thorough drying, just within the outer mantle, on the side next the spectroscope, with the axis transverse to the slit of the spectroscope and the handle across the body of the flame. In cleaning the coils we have found it convenient to heat them in the flame of an Argand burner of the Fletcher pattern, beneath which is burned, in a small lamp, alcohol containing about a twentieth of its volume of chloroform. The products of combustion of the alcohol and chloroform are conveyed to the interior of the flame above by a glass funnel fitted by a cork to the tube of the Argand burner. This arrangement of apparatus gives a hot colorless flame through which hydrochloric acid is constantly diffused in condition to clean the wires completely and without attention. The spectroscope which we have employed is a well-made single prism instrument provided with a scale, and a movable observing telescope so that different portions of the spectrum may be viewed or cut off at will. The slit is adjustable, but for measuring its width we have been obliged to have recourse to the device of closing it upon wires of known gauge. Our work has been done in the ordinary diffused light of the laboratory, care having been taken to cut off from the room direct sunlight only; but in observing it has been our custom to shield the eye in use as completely as possible with the hand or with

a dark handkerchief, and to cover the eye not in use. We have found it desirable to use the scale of the instrument, illuminated to the lowest degree of visibility, to aid the eye in placing barely visible lines.

Upon experimenting with the apparatus described, it was found that the largest coil used was best adapted to our purpose, and, accordingly, in all the experiments made subsequently, and recorded in the following account, coils holding $\frac{1}{50}$ of a gram of water, measuring 2 mm. in diameter by 1 cm. in length, made of No. 28 wire (0·32 mm. in diameter), and wound in about thirty turns, were the ones employed. With these coils and the flame adjusted to a height of 20 cm. we have been able to recognize the presence of potassium, taken in the form of the chloride, in a coil-full of liquid containing 0·00066 grm. of the metal in 10 cm.^{3}, when the slit had a width of 0·18 mm.; and containing 0·0005 grm. in the same volume of solution, when the slit was set 0·23 mm. wide. That is to say, $\frac{1}{750}$ mg. of potassium to the coil-full produces a line distinctly visible with a slit of 0·18 mm., and $\frac{1}{1000}$ mg with a slit of 0·23 mm., and it is evident that this practical method of producing the spectrum of potassium gives results of a delicacy approaching that indicated in the experiments of Bunsen and Kirchhoff.

These determinations were made with pure potassium chloride carefully prepared from the chlorate, but in practical analysis it almost always happens that sodium is also present. Experiments were therefore made to determine the influence of varying amounts of the latter upon the visibility of the potassium line. The dilution of the potassium chloride was adjusted nearly to the last limit of visibility, so that a coil-full of the liquid should contain $\frac{1}{750}$ mg., or $\frac{1}{1000}$ mg. of the element, according as the slit was 0·18 mm. or 0·23 mm. wide; to this solution were added weighed amounts of pure sodium chloride twice reprecipitated and washed by hydrochloric acid; and the spectroscopic tests were carried out as before, the sodium line being kept within the field of view with the potassium line.

Weight of K in a coil-full.	Weight of Na in a coil-full.	Ratio of Na : K.	Width of slit.	Number of trials.	Characteristic of line.
0·0010 mg.	0·0000 mg.	0 : 1	0·23 mm.	3	visible
0·0010 "	0·0020 "	2 : 1	0·23 "	3	visible
0·0010 "	0·0100 "	10 : 1	0·23 "	3	visible
0·0010 "	0·0200 "	20 : 1	0·23 "	3	visible
0·0010 "	0·0400 "	40 : 1	0·23 "	3	visible
0·0010 "	0·0500 "	50 : 1	0·23 "	4	very faint or none
0·0010 "	0·1000 "	100 : 1	0·23 "	3	none
0·0010 "	0·2000 "	200 : 1	0·23 "	3	none
0·0014 "	0·0000 "	0 : 1	0·18 "	3	visible
0·0014 "	0·0560 "	40 : 1	0·18 "	3	visible
0·0014 "	0·0700 "	50 : 1	0·18 "	3	visible
0·0014 "	0·1400 "	100 : 1	0·18 "	2	visible
0·0014 "	0·1400 "	100 : 1	0·18 "	2	none

It is obvious from these results that a considerable amount of sodium may be present in the flame, when the sodium line is in full view in the spectrum, and the slit adjusted to nearly the lowest limit of visibility of pure potassium, without interfering with the appearance of the potassium line, but that a quantity of sodium amounting to a hundred times that of the potassium is sufficient to entirely overpower the spectrum of the potassium. The inference is plain that the proportion of sodium to potassium should not be permitted to reach 100 : 1 when it is desirable to bring out the full delicacy of the spectroscopic test with the sodium line in the field of view. When too great a proportion of sodium is present, its influence may be moderated by throwing the sodium line out of view, if the instrument in use possesses the necessary adjustment; otherwise, it is easy to effect a partial separation of the sodium chloride from the potassium chloride, before bringing the solution to the test, by precipitating with alcohol. Our experience shows that the delicacy of the test for potassium is not impaired materially by such treatment of the mixed chlorides. We found, for example, that 0·0070 grm. of potassium chloride mixed with 0·5 grm. of pure sodium chloride, dissolved in the least amount of water, and extracted carefully by about 7 cm.^{3} of absolute alcohol applied in successive portions, was so completely retained in solution and separated from sodium, that a coil-full taken from the solution diluted to 140 cm.^{3} gave the spectroscopic test for potassium distinctly with the slit at 0·23 mm. In this case, at least, the treatment did not diminish the delicacy of the test; for, a coil-full of the diluted solution could not have contained more than $\frac{1}{1000}$ mg. of potassium, if nothing had been lost. It was found, in like manner, that, by taking pains to evaporate the alcoholic extract, and to dissolve the residue in a drop of water, 0·0001 grm. of potassium originally present as the chloride with 0·5 grm. of sodium chloride, was easily found. By turning the observing telescope so as to cut off as completely as possible the sodium light we were able to detect potassium in four successive tests of a drop of the final solution which was just large enough to fill the coil four times, when the original amount of potassium present with 0·5 grm. of sodium chloride was 0·00001 grm. This is equivalent to detecting $\frac{1}{400}$ mg. of potassium in a drop large enough to fill the coil once. We were assured of the entire absence of potassium from the sodium chloride which we used by the fact that the similar extraction of 1 grm. of the salt by alcohol left a residue which yielded no line of potassium when examined spectroscopically. It is perhaps worth noting in passing that the coil may be

made to pick up a drop of a size only sufficient to fill it by simply touching the coil while hissing hot to the drop.

Certain experiments in which the method of manipulation which we have described was applied to the determination of potassium salts other than the chloride indicated that the test is less delicate in the case of the sulphate, and rather more delicate in the case of the carbonate. We were able to find the red line of potassium unmistakably, when only $\frac{1}{2000}$ of a milligram of potassium was introduced into the flame in the form of the carbonate.

The quantitative determination of potassium by the spectroscope has never, so far as we know, been accomplished heretofore. Sodium appears to have been successfully estimated by Champion, Pellet and Grenier* by the use of comparison flames, produced by the aid of complex mechanism, and a spectrophotometer of original construction. Lithium has been determined more simply, Truchot† having been the first to suggest a method of manipulation which was modified by Ballmann‡ and taken up later by Bell§ apparently without knowledge of the previous work on the same line. Truchot's method consists in comparing the duration and strength of the spectral lines developed by exposure to the Bunsen flame of portions taken up in a platinum loop from the test-solution and standard solutions of different strengths. No analytical proofs of the value of the method were given and accuracy was not claimed beyond the recognition of differences of from three to four milligrams in a liter of liquid when amounts not exceeding forty milligrams per liter were compared. Ballmann discards as valueless the observation of the duration of the spectral line, advocates the dilution of the test and standard solutions to the absolute extinction of the line, and employs hollow cones, measuring $2{\cdot}5^{mm}$ by $3{\cdot}5^{mm}$, to carry the liquids to the flame. Bell follows Ballmann's method of diluting the solutions to be compared to a common condition, but takes the vanishing point of the line instead of the point of absolute invisibility and makes his loops of platinum very small. Both Ballmann and Bell were able to estimate thallium similarly, but neither determined potassium, Bell declaring specifically that the method is inapplicable to the handling of that element.

Our success in determining potassium qualitatively by the use of powerful flames and coils of large dimensions was such as to encourage the attempt to apply quantitatively the same method of manipulating; and from certain preliminary experi-

* Compt. Rend., lxxvi, 707.
‡ Zeitschr. für Anal. Chem., xiv, 297.
† Compt. Rend., lxxviii, 1022.
§ Am. Chem. Jour., vii, 35.

ments looking in this direction we found it best, for our purpose at least, to fall back upon Truchot's method of comparing visible lines, rather than to try to fix the vanishing point or the point of extinction of the spectral line. We chose a dilution of the standard solution which corresponds to the presence of $\frac{1}{500}$ mg. of potassium to the coil-full, and set the slit at a width of $0{\cdot}23^{mm}$, having found it most advantageous to work with lines for comparison bright enough to be visible without much effort. Our mode of proceeding is to dilute the test-solution until the line given by the potassium contained in a coil-full is of the same brightness as that given by the same quantity of the standard solution. From the final volume of the test-solution the quantity of potassium present in it is directly calculable; for, since any given volume of the test-solution at its final dilution contains exactly the same amount of potassium as the same volume of the standard solution, we have only to multiply the number expressing the volume in cubic centimeters of the test-solution by the weight in grams of the potassium contained in one cubic centimeter of the standard in order to obtain the weight in grams of potassium in the whole test-solution. We found it convenient to use several coils adjusted to the same capacity, and to clean, fill, dry and ignite them before the spectroscope in the manner previously described. From time to time the capacity of the coils should be readjusted, or else the final comparison tests should be made with a single coil. It is essential that the eye of the observer should be kept as nearly as possible in the same condition of sensitiveness and in the same position in making the comparisons, and to accomplish this end we found it best to hold the eye at the observing telescope during the entire interval between the exposures, to shade it carefully by the hand, or otherwise, to cover the eye not in use, to cut off all direct sunlight from the work-table (though the diffused light of the room is not objectionable), and to light the comparison scale of the spectroscope to the faintest possible visibility in order to fix exactly the position in which the line is to be sought. It is important, too, that the trials of the test and standard should come as closely together as possible in point of time. The observations of a series should be made by the same individual, the preparation and exposure of the wires being made by another. It is not possible to attain the best results in such work single handed. The dilution of the test-solution is made conveniently, and with sufficient accuracy, in 100cm.^{3} cylinders graduated to half cubic centimeters, the mixture being made thorough by passing the solution from vessel to vessel. It is often advantageous to divide a liquid which is to be diluted and to work with aliquot portions, so that it may be possible to

retrace a step without trouble in case a portion of the solution has been unwittingly diluted too much; such a mode of proceeding is, of course, necessary when the final dilution must exceed 100 cm^3, unless large graduates are called into use. Excepting the cases of very concentrated solutions, no significant loss of material is occasioned by the filling of the coils, the error thus introduced being trivial in comparison with that inherent in all photometric processes. The following is the record of our experience in the comparison of solutions of pure potassium chloride, the strength of the test solution being unknown to the observer.

Experiment I.

Volume of test-solution.	Characteristic of line compared with standard.
20 cm^3	stronger
50 "	stronger
100 "	stronger
110 "	stronger
120 "	stronger
150 "	like
200 "	weaker
160 "	weaker
150 "	like

Experiment II.

Volume of test-solution.	Characteristic of line compared with standard.
30 cm^3	stronger
60 "	stronger
82 "	weaker
70 "	stronger
76 "	stronger
78 "	stronger
80 "	like

($150 \times 0{\cdot}0001 = 0{\cdot}0150$)	
Potassium found	0·0150 grm.
" taken	0·0150 "
Limits on either side	0·0120 " to 0·0160 "
Error	0·0000 "

($80 \times 0{\cdot}0001 = 0{\cdot}0080$)	
Potassium found	0·0080
" taken	0·0080
Limits on either side	0·0078 to 0·0082
Error	0·0000

These results show a degree of accuracy in the process quite unexpected. In the former no attempt was made to approximate as closely as possible to the limits of dilution on both sides of the condition of equal brightness in test and standard, but in the latter great care was taken in this respect and the possible error cannot exceed two and a half per cent of the entire amount of potassium involved.

Experiment III was made to discover the effect of the presence of a reasonable amount of sodium chloride upon the determination of the potassium. To a portion of the solution if pure potassium chloride containing 0·01 grm. of the element was added 0·1 grm. of sodium chloride taken from the salt purified as previously described. This solution was diluted and the comparison made with the standard according to the accompanying account.

EXPERIMENT III.

Volume of the test-solution.	Characteristic of line compared with standard.
25 cm³	stronger
50 "	stronger
80 "	stronger
90 "	stronger
95 "	stronger
105 "	stronger
120 "	like

(120 × 0·0001 = 0·0120)

Potassium found	0·0120 grm.
" taken	0·0100 "
Error	0·0020 "

The result of this experiment was most surprising; for, instead of diminishing the delicacy of the test we find that the presence of a moderate amount of sodium chloride tends to increase the brilliance of the potassium line. The sodium chloride employed was a part of that prepared and tested as previously described and used in the experiments upon the qualitative determination of potassium. By no possibility could the 0·1 grm. of it taken in the experiment have contained more than 0·000001 grm. of potassium. It is evident, therefore, that the brilliance of the potassium line gained twenty per cent in strength by the influence of sodium chloride amounting to ten times the weight of the potassium present when the effect due to impurity of the salt could by no means exceed a hundredth of one per cent; that is to say, the observed effect is, at the very least, two thousand times greater than that which might have been conceivably produced by contamination of the sodium salt.

In the following experiment the effect of varying amounts of sodium chloride upon the spectrum of the potassium is shown. The sodium line was turned out of the field of view to obviate the dazzling effect of the sodium light, and a solution of potassium chloride containing 0·01 grm. of the element in 100 cm³. was examined spectroscopically after the addition of successively increasing amounts of sodium chloride, the strength of the line observed being brought into comparison with that produced by similar portions of the potassium solution containing no sodium.

Sodium chloride in a coil-full.	Potassium in a coil-full.	Ratio of NaCl : K	Width of slit.	Characteristic of line compared with standard containing no NaCl.
0·002 mg.	0·002 mg.	1 : 1	0·18 mm.	like.
0·010 "	0·002 "	5 : 1	0·18 "	like.
0·020 "	0·002 "	10 : 1	0·18 "	a little stronger.
0·040 "	0·002 "	20 : 1	0·23 "	much stronger.
0·200 "	0·002 "	100 : 1	0·23 "	very much stronger.
0·400 "	0·002 "	200 : 1	0·23 "	much stronger.
0·600 "	0·002 "	300 : 1	0·23 "	much stronger.

From this it appears that the maximum strengthening effect occurs when the sodium chloride stands to the potassium in the ratio of 100 : 1. The apparent diminution of brilliance when the sodium is increased beyond that proportion is doubtless due to the effect of the strong light diffused through the field of view by the intensely bright sodium flame in spite of the fact that the line itself is cut off from direct vision.

The cause of the brightening effect of the sodium chloride we are inclined to attribute to the chemical action of the sodium dissociated in the flame. The effect of ammonium chloride, and of hydrochloric acid, in destroying the potassium light is well known, and is due, presumably, in very large degree to the prevention of the dissociation of the potassium chloride. The dissociated sodium should naturally by its mass-action reinforce the disintegrating action of the heat upon the molecule of potassium chloride.

It is plain that the complication introduced into the quantitative spectroscopic determination of potassium by the presence of the sodium salt in the test can be obviated if it can be brought about that both the test and the standard solution shall contain the same amount of that reagent. It is a matter of interest, therefore, to discover whether it is possible to match sodium lines of considerable intensity so closely that the quantities of that element in solutions brought into comparison shall be practically equal, and so may be relied upon to give the same strengthening effect to the potassium spectrum. The following statement is the record of an attempt in this direction. The narrower slit was found to be best adopted to the comparison of the sodium lines.

NaCl in a coil-full of new solution.	NaCl in a coil full of standard.	Width of slit.	Characteristic of line as compared with that of standard.
0·010 mg.	0·02 mg.	0·18 mm.	weaker.
0·017 "	0·02 "	0·18 "	weaker.
0·019 "	0·02 "	0·18 "	weaker.
0·020 "	0·02 "	0·18 "	like.

The result shows the possibility of matching the sodium lines with a degree of approximation sufficient for the purpose in view; and, accordingly, a new standard solution was made containing 0·01 grm. of potassium taken in the form of the chloride and 0·1 grm. of sodium chloride in 100 cm³. and with this new standard the following determinations were made. The experiment was performed in three stages: first, the test solution was diluted until its potassium line matched approximately with that of the standard; secondly, sodium chloride was added to the solution thus diluted until the sodium lines were brought to equality; and, finally, the test solution and the standard were again brought into comparison.

EXPERIMENT IV.

PART I.			PART II.			PART III.		
Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.	NaCl in 100 cm.³ of test-solution.	Width of slit.	Characteristic of sodium line as compared with standard.	Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.
30 cm.³	0·23 mm.	Stronger	0·01 grm.	0·18 mm.	Weaker	108 cm.³*	0·23 mm.	Weaker
70 "	0·23 "	Stronger	0·03 "	0·18 "	Weaker	108 "	0·23 "	Stronger
100 "	0·23 "	Weaker	0·05 "	0·18 "	Weaker			
			0·08 "	0·18 "	Weaker	109 "	0·23 "	Weaker / Stronger
			0·09 "	0·18 "	Weaker			Like
			0·10 "	0·18 "	Like			

EXPERIMENT V.

PART I.			PART II.			PART III.		
Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.	NCl in 100 cm.³ of test-solution.	Width of slit.	Characteristic of sodium line as compared with standard.	Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.
40 cm.³	0·23 mm.	Stronger	0·025 grm.	0·18 mm.	Weaker	160 cm.³	0·23 mm.	Stronger
100 "	0·23 "	Stronger	0 050 "	0·18 "	Weaker	180 "	0·23 "	Stronger
160 "	0·23 "	Weaker	0·085 "	0·18 "	Weaker	190 "	0·23 "	Stronger
			0·100 "	0·18 "	Weaker	200 "	0·23 "	Stronge
			0·110 "	0·18 "	Like	205 "	0·23 "	Weaker[r]
						210 "	0·23 "	Weaker

$$\left(\begin{matrix} 205 \times 0{\cdot}0001 = 0{\cdot}0205 \\ 200 \times 0{\cdot}0001 = 0{\cdot}0200 \end{matrix}\right\} \text{mean} = 0{\cdot}02025\right)$$

Potassium found ..... 0·02025 grm.
" taken ..... 0·02000 "
Error ..... 0·00025 " = 1·25 per cent.

EXPERIMENT VI.

PART I.			PART II.			PART III.		
Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.	NaCl in 100 cm.³ of test-solution.	Width of slit.	Characteristic of sodium line as compared with standard.	Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.
40 cm.³	0·23 mm.	Stronger	0·045 grm.†	0·18 mm.	Weaker	110 cm.³	0·23 mm.	Stronger
80 "	0·23 "	Stronger	0·082 "	0·18 "	Like	120 "	0·23 "	Stronger
100 "	0·23 "	Stronger				130 "	0·23 "	Like
110 "	0·23 "	Like						

* Originally present.

$(130 \times 0{\cdot}0001 = 0{\cdot}0130)$

Potassium found ..... 0·0130 gram.
" taken ..... 0·0140 "
Error ..... 0·0010 " = 7 per cent.

† The test-solution having been accidentally over-diluted, its strength was increased by the addition of 0·0010 grm. of potassium and this amount was added in the computation below to that originally in the test-solution.

$(109 \times 0{\cdot}0001 = 0{\cdot}0109)$

Potassium found ..... 0·0109 grm.
" taken ..... 0·0110 "
Error ..... 0·0001 " = 0·9 per cent.

EXPERIMENT VII.

PART I.			PART II.			PART III.		
Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.	NaCl in 100 cm.³ of test-solution.	Width of slit.	Characteristic of sodium line as compared withstandard.	Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.
						First.		
30 cm.³	0.23 mm.	Stronger	0·05 grm.*	0·18 mm.	Weaker	100 cm.³	0·23 mm.	Stronger
90 "	0·23 "	Stronger	0·07 "	0·80 "	Weaker	120 "	0·23 "	Stronger
100 "	0·23 "	Weaker	0·09 "	0·18 "	Weaker	130 "	0·23 "	Stronger
		Like	0·10 "	0·18 "	Like	140 "	0·23 "	Stronger
					Stronger		*	Weaker
					Stronger			
						Second.		
						120 cm.³	0·23 mm.	Stronger
						140 "	0·23 "	Stronger
						150 "	0·23 "	Stronger
								Weaker
						160 "	0·23 "	Weaker

First.		Second.	
(140 × 0.0001 = 0·0140)		(150 × 0·0001 = 0·0150)	
Potassium found	0·0180 grm.		0·0150
" taken	0·0150 "		0·0150
Error	0·0010 "=7 per cent		0·0000

From these results it is plain that the sodium in test and standard may be matched closely enough to allow a fair approximation to be made in the determination of the potassium. In Experiments IV, V and VI, no readjustment of the percentage of sodium in the final dilution, subsequent to the matching of the sodium lines, was attempted; in Experiment VII this point was looked to, so that in this determination the strength of the sodium was kept equal to that found in the matching process. In Experiments IV and VII, the matching of the sodium in the test-solution against that in the standard proved to have been exact; in V, an excess of 10 per cent was added, and in VI, the point of equality was thought to have been reached while there was still a deficiency of 25 per cent in the sodium chloride of the test-solution.

The error in the determination of the potassium in Experiment VI may, perhaps, be accounted for by the mistake in matching the sodium; that of the first attempt in Experiment VII, we are disposed to attribute to lack of care in keeping the eye of the observer in the most sensitive condition, and of attention to the point of bringing the wires to the plane in quick succession. The largest absolute error met with amounted to one milligram in a total of fifteen. Though not accurate to

*Originally present.

the last degree when large amounts of potassium are to be estimated, the method, we think, offers some advantage without too great sacrifice of exactness in the determination of small amounts. In qualitative work the mode of manipulating described is exceedingly satisfactory. Aside from the practical application of the method the point which has been of greatest interest to us is the development of the fact that the presence of sodium salts in the flame is of direct influence in strengthening the spectrum of potassium.

Art. XLIX.—*The Ultra-Violet Spectrum of the Solar Prominences;* by George E. Hale.*

In various papers published during the past year, I have called attention to some of the advances in our knowledge of the Solar Prominences which might be expected to follow the application of photographic methods to a study of their forms and spectra. A recent number of this Journal, August, 1891, p. 160, contains reproductions of some photographs obtained in the course of my investigations on this subject at the Kenwood Physical Observatory. I am indebted to Professor Lockyer for the use of a measuring machine during a recent visit to London, and I am now able to give my determinations of wave-length for the new prominence lines, and some conclusions to be drawn from them. But perhaps it will first be well to consider for a moment the apparatus and methods at present employed in the work.

To the eye end of the 12·2 inch equatorial refractor of the Kenwood Observatory a large solar spectroscope is rigidly attached by three steel tubes, and as the spectroscope extends about five feet beyond the focus of the telescope, the declination axis is placed at the center of the combined lengths of the two instruments, in order to reduce the amount of counterbalance required at the object-glass end. The result is very satisfactory, and there can certainly be little fear of flexure in the combination. The whole spectroscope may be rotated by a rack and pinion, so as to make the slit tangential or radial at any point on the sun's limb. The object-glasses of the collimator and observing telescope have $3\frac{1}{4}$ inches clear aperture, and $42\frac{1}{2}$ inches focal length. The 4-inch Rowland grating is ruled with 14,438 lines to the inch, and as the telescopes make with each other a constant angle of 25°, different orders of

* Read at the Cardiff Meeting of the British Association for the Advancement of Science, August, 1891.

spectra are brought into the field of view by rotating the grating. A diagonal eye-piece at the end of the observing telescope allows the spectrum to be observed after the photographic plate is in position.

In photographing the spectrum of a prominence the following is the ordinary process. Let us suppose that it is desired to use a radial slit, in the H and K region of the spectrum. The C line in the second order is brought into the field, and while observing this line the spectroscope is rotated until the slit is radial at some point on the limb where a prominence is seen. The driving-clock is then started, and the telescope clamped, so that the sun's image is kept as nearly as possible stationary on the slit plate. A small strip of metal, pushed in just behind the slit, excludes the direct solar light, except from a small region near the limb. The whole collimator is next moved by a screw until the slit is brought to the proper focus of the equatorial for K, and the collimator and observing telescope are set at the focus for the same line, the positions being taken from a table of foci, determined by experiment, for the principal lines in the spectrum. After placing the sensitive plate in position, the grating is rotated until the K line in the fourth order is in the middle of the field, the slit is covered, the slide drawn, and the proper exposure given. The exposure of course depends upon the aperture and focal length of the equatorial, the width of the slit, the brilliancy of the grating, the sensitiveness of the plate, etc., but with the ordinary dry plate of sensitometer No. 23 furnished by the Seed Company, and a slit about 0·001 inches wide, I usually find that an exposure of from 20 to 30 seconds gives the best result.

For the first time without an eclipse the prominence spectrum was thus photographed early in April of the present year. The only bright lines then obtained were found to fall nearly at the centers of the dark bands H and K of the solar spectrum, but these were remarkably strong, seeming to fully equal C in intensity, and were present in every prominence photographed. Work was continued on the violet and ultra-violet for some weeks, but, with the exception of some lines which had all the appearance of ghosts of the brilliant H and K reversals, no new lines were discovered until June 23, when an exceptionally bright prominence was found. This gave four lines in the ultra-violet, and the least refrangible of these was found to be double. A line slightly less refrangible than H, nearly but not quite at the position where the first ghost would be expected to fall, was much stronger than any of the other ghosts, and it seemed very possible that it was an independent line. This prominence remained visible for several days, and

a number of photographs of its spectrum were made with both radial and tangential slit.

In reducing the wave-lengths of these lines it might be considered easy to obtain values for a given line agreeing closely in the hundredths place of tenth-meters, but two causes have combined to lessen the accuracy of determinations. The H and K reversals almost invariably show some indications of motion of the prominences in the line of sight, and the consequent distortion renders somewhat difficult the proper setting of the spider line of the measuring machine. Again the plate-holder used was made for another purpose, which required that the plane of the plate should be at right angles to the axis of the observing telescope. As the object-glass of the telescope is corrected for the visual region, it is evident that near K there must be a slight change in focus from one side of the plate to the other, and a small error is thus introduced. It will be seen, however, that the measures are sufficiently accurate to allow very little doubt as to the identity of most of the lines. The fact that the solar spectrum, due to the diffuse light of the atmosphere, is photographed simultaneously with the prominence spectrum, is of great advantage in determining the position of the prominence lines, though it has a corresponding disadvantage in concealing very faint lines, which would otherwise be brought out. The wave-lengths of certain standard lines in the solar spectrum have been taken from the list published by Professor Rowland,* and it has thus been easy to find the wave-lengths of the prominence lines by simple interpolation. The value of the micrometer screw has been determined for several regions on every plate by measuring the positions of properly distributed standard lines, the number of separate settings of the spider line in each case ranging from five to fifteen, depending upon the character of the line measured. In the following table the first column contains the wave-lengths of the ultra-violet prominence lines; the second the positions assigned by Ames to the lines in the hydrogen stellar series; and the third, the wave-lengths of the calcium lines at H and K, which Professor Rowland has been kind enough to furnish in advance of publication. I am informed that they are provisional only, but may be relied on to within 1 or 2 in the last place of decimals. In the case of hydrogen, Ames considers that the error in any wave-length cannot amount to more than 0·05 of a unit,† and my own values for the prominence lines must possess at least an equal degree of accuracy, though I am inclined to believe some of them even more reliable. In the fourth and fifth columns I

* This Journal, p. 182, 1887. † Phil. Mag., July, 1890, p. 49.

have added Cornu's measures of the hydrogen lines,* and Dr. Huggins' wave-lengths of lines in the hydrogen stellar series,† both reduced to the scale of Rowland's map.

Prominences.	Hydrogen.	Calcium.	Hydrogen.	First Type Stars.
Hale.	Ames.	Rowland.	Cornu.	Huggins.
3968·56	----	3968·61 (H)	----	----
3933·86	----	3933·80 (K)	----	----
3888.73	----	----	----	----
3970·11(?)	3970·25	----	3969·6	3969·6
3889·14	3889·15	----	3888·5	3888·2
3835·54	3835·6	----	3835·1	3834·6
3798·1	3798·0	----	3797·5	3795 6
3770·8	3770·7	----	3770·0	3768·1
----	3750·15	----	3749·9	3746·1
----	3734·15	----	3734·2	3730·6
----	3721·8	----	3721·1	3717·9
----	3711·9	----	3711·1	3707·9
----	----	----	----	3699·4

Let us first consider the prominence lines which lie near the centers of the broad dark shades at H and K. In his observations of the chromosphere and prominence spectrum at Mount Sherman, in 1872, Professor Young succeeded in seeing these reversals in a number of cases, but the character of the bright lines could not be made out, and it was considered probable that the broad dark bands were included in the reversal, only the brighter central portions, however, being strong enough to affect the eye. We now find, on the contrary, that the substance producing the bright prominence lines may possibly be entirely distinct from that causing the broad bands in the solar spectrum, for though the lines certainly do lie near the centers of the bands, they are narrow and sharp, and it is easily conceivable that their position may be simply the result of chance, though perhaps probability would point the other way. We are hardly in a position to discuss the cause of the unique appearance of the dark H and K bands, but it may be that we may learn something in this connection from Dr. Huggins' important investigations of stellar spectra. It will be remembered by everyone that in his memoir "On the Photographic Spectra of Stars" communicated to the Royal Society in 1880, Dr. Huggins arranged the stars observed in a series, in which the principal criterion of position was the character of the K line. In Arcturus, for instance, this line is broader and more diffuse than in the sun itself, while in Sirius it has narrowed down to

* Journal de Physique, 1886. † Phil. Trans., Part II, 1880, p. 669.

a fine, sharp line. Other stars give intermediate breadths, and in some instances it has entirely disappeared. In the case of H the question is complicated by the fact that hydrogen and calcium possess lines which form a close double at this point, so it is best to consider only K. From the variations of this line it will be seen, apart from the interesting subject of stellar evolution so evidently suggested, that the narrow dark line at the center is very possibly produced by the same substance which, vibrating under different conditions, causes by its absorption the broad dark band.

As the central dark line is known with a high degree of certainty to be due to calcium, it becomes likely that the band is due to the same substance, and as the central dark line of H is also a calcium line, it might perhaps be safe to attribute the H band to the same metal, though in neither case is it well to be too positive in the assertion, for it is somewhat peculiar that the bands and lines appear together in the solar spectrum. If the same substance produces both, and each requires different conditions, possibly of temperature or pressure, for its production, these conditions must presumably exist at different elevations above the photosphere.

The question now arises whether the bright lines in the prominence spectrum agree in position with the dark lines at the center of the H and K bands. Only one or two of my prominence spectra happened to be given the proper exposure to bring out both the bright and dark lines, but in these the coincidence is fairly satisfactory. I have not as yet, however, been able to obtain the wave-lengths of the dark lines in hundredths of a tenth-meter, but Professor Rowland's determinations of wave-lengths for the corresponding calcium lines will answer nearly as well. These have been given in the third column of the table of wave-lengths. It will be seen that in the case of H the prominence line is 0·05 tenth-meters more refrangible, while at K the prominence line is 0·06 tenth-meters less refrangible. Professor Rowland considers his values correct within 1 or 2 hundredths tenth-meters, while the probable errors in the position of the prominence lines, deduced on the assumption of equal weights for the wave-lengths given by each of six plates, are 0·021 and 0·036 tenth-meters for H and K respectively. On the whole, then, there can be little doubt that these prominence lines are due to calcium, and are therefore probably true reversals of the central dark lines of the H and K bands.

It will be of interest next to consider briefly the character of these two prominence lines. In all cases they are quite narrow and sharp, except when motion in the line of sight has produced broadening or distortion. In seven photographs made

with a radial slit both lines gradually become narrower as the distance from the limb increases, and have a pointed appearance. This might be due to an actual decrease in the width of the lines, but, as there is usually a certain increase of intensity toward the limb, the effect may be purely photographic. In several plates, however, there is so little change of intensity that the widening can hardly be due to this cause. The arrow-head appearance so frequently seen with the C and F lines, is often shown when the slit is radial. A rather curious appearance has been found on three plates made with radial slit, and in the two which best show the effect there is a very sudden decrease of intensity in the upper part of the lines. Instead of becoming narrower toward the top, the lines seem to expand symmetrically on either side, and the edges become hazy and indistinct. As in the case of the pointed lines, there is also an expansion toward the limb, but here the edges are clearly defined. The arrow-head appearance is shown in two of these plates. With a tangential slit two plates show the lines expanded at the ends, and in one plate they are pointed. Though in most cases the forms of H and K are very similar, there is a single instance where K is shown sharply double in the fainter portions at each end of the line, and at one end the components seem to diverge slightly. That this is not the result of poor focusing is attested by the sharpness of the lines in the background of solar spectrum; at the same time the appearance is hardly that of an ordinary reversal. One further peculiarity will show that it is safest, for the present at least, not to draw any conclusions from such appearances as have been noted. In a certain position of the mirror of the measuring machine the illumination was such that the edges of the radial black lines appeared bright, while the Fraunhofer lines of the solar spectrum were also bright, as with ordinary illumination. One of the negatives, in which H and K were broader and fainter at the top, brought out the effect particularly well. The central dark line extended two-thirds of the distance to the top of the prominence, and in the upper part it was excessively narrow and delicate. Lower down it gradually widened, until at a point very near the limb the widening became much more rapid, and at the limb itself the line was nearly as wide as when seen under ordinary conditions.

A paragraph from Dr. Schuster's report on the results obtained with the spectroscopic cameras at the total eclipse of August 29, 1886, seems to refer to a somewhat similar appearance. Speaking of the photographs of the coronal spectrum, Dr. Schuster remarks:* "A bright line shows black on the negative, and is bounded on both sides by an apparently lighter

* Phil. Trans., vol. clxxx, (1889), (A.), p. 328.

background. This is a well-known contrast effect. The H and K lines, for instance, seem to be surrounded by a lighter band, which follows the contour not only of the lines, but also of the wing by the side of the prominence. If, now, a Fraunhofer line happens to be by the side of a bright line, the contrast is strengthened, and both the bright and the dark lines appear more distinctly than they otherwise would. This is the only simple way in which I can explain some of the appearances of the photographs." The first part of the quotation is all that concerns us at present, for in the negative which I have mentioned as showing this peculiarity particularly well, the Fraunhofer lines are hardly visible above the limb, and none appear within the dark bands at H and K. As Dr. Schuster does not speak of the illumination, I assume that the appearance was generally seen, and this constitutes another point of difference. A penumbra formed by light reflected from the back of the plate would probably extend but little higher than the central line, but in the future plates backed with a dyed collodion film will be employed to obviate any effects of this kind. No entirely satisfactory explanation of the peculiar appearance of these lines has as yet suggested itself.

But on another point there is little room for doubt. The bright H and K lines certainly extend to a very considerable elevation above the sun's limb, and it is extremely probable that calcium is carried to the very top of the highest prominences. With the improved apparatus to be used in a continuation of this research, I hope to be able to ascertain the relative heights of various lines in the prominence spectrum. For instance, while a photograph is being made of H and K, the height of C in the same prominence can be measured with a micrometer. The comparative observations and photographs made up to the present time suggest the belief that calcium attains the highest elevations reached by hydrogen, and the remarkable brilliancy of H and K at the eclipse of 1882 attest the importance of calcium in the prominences. Dr. Schuster is of the opinion that the coronal spectrum contains calcium injected by the prominences, and this may only very gradually descend again to the level of the photosphere.* This supposition seems a very plausible one, and if it be at the same time considered probable that the H and K bands and their central lines are produced by the same substance, the possibility is suggested that the broad dark shades may be caused by the absorption of the cooler vapor at a considerable elevation, while the absorption near the photosphere gives rise to the narrow central lines. This view need not necessarily conflict

* Phil. Trans. vol. clxxx, 1889, (A.), p. 328.

with a belief in a shallow reversing layer, where absorption ordinarily takes place, for the H and K bands are unique in the solar spectrum. It rests, however, on somewhat insecure foundations, and cannot be credited with much weight.

On account of the dark shades at H and K it has proved quite easy to photograph prominence forms with an open slit. With other prominence lines the brilliancy of the background is much increased when the slit is opened, but this is not the case with H and K, and it is often possible to use a slit nearly a quarter of an inch wide. The fourth order spectrum has been employed for this work, and the best results are obtained with an exposure of about one second. It is considered that great advantage will result from a material reduction of this exposure, as the disturbances in our atmosphere have as yet made it impossible to secure the finest details of structure.

It is of interest to note, however, that the first photograph ever taken of the rapid development of a prominence was made in this way by my assistants on July 8, 1891, at 23h. 45m., Chicago M. T. As at first observed through C, the prominence was low, but very bright, and changing rapidly. A great tongue moved rapidly out to an elevation of about 80,000 miles, and at this time the extension was photographed through H and K. In fifteen minutes the prominence had returned to its original form. A reproduction of the photograph is given in the August number of this Journal, and though much has been lost in the printing process, some idea of the actual appearance of the prominence may be gained. A new apparatus for photographing the prominences is now being constructed as the outcome of my investigations on this subject, and this is expected to do away with many of the difficulties previously encountered. It will consist of two curved slits, moved in opposite directions across the ends of the stationary collimator and observing telescope by means of a peculiar form of clepsydra. The sun's image and photographic plate will be stationary, and the apparatus is thus to be constructed on the principle of the second method devised by myself in 1889, but so altered as to avoid the defects of the original scheme.*

Decision must be reserved for the present as to the line at λ 3970·11. The wave-length has been determined from four plates, and its probable error is 0·030, but as the line is not far from where a ghost of H should fall, I cannot be certain that it belongs to the prominence spectrum. At the same time it is

* For previous papers on prominence photography see—Technology Quarterly, vol. iii., No. 4, 1890; Astronomische Nachrichten, Nos. 3006, 3037 and 3053; Sidereal Messenger, June, 1891; This Journal, August, 1891.

very much brighter than any other of the seven ghosts of H and K, and its position with respect to H is not symmetrical with that of the first ghost on the opposite side of this line, while in the case of K the ghosts are very regularly spaced. My assistants report that they were able to *see* H very plainly double in a brilliant metallic prominence observed July 27, and on one or two occasions Professor Young has made out the same thing. The agreement in wave-length with Ames's hydrogen line at 3970·25 is by no means satisfactory, and more observations and measures are required before a conclusion can be reached.

No one can doubt that the next four prominence lines are members of the well-known hydrogen series, for their agreement in wave-length with the values given by Ames is certainly very striking. Cornu's measures show considerable differences, as do also those of Dr. Huggins, but the small dispersion employed by the latter in this investigation must be borne in mind. There can be little question that Ames' wave-lengths are very near the truth, for they almost exactly correspond with those calculated by Balmer's formula. The measures of the prominence lines also serve to confirm them.

The remaining prominence line at λ 3888·73 has not been accounted for. It forms a close double with the hydrogen line at λ 3889·14, and with it attains as great elevations above the limb as those reached by H and K. The character of the lines, however, is quite different, for while the hydrogen line is wider, and slightly diffuse, the line at λ 3888·73 is very narrow and sharp. I have seen no statement that the hydrogen line has shown any signs of duplicity, and, as Mrs. Huggins has had the kindness to examine the corresponding line in some very sharp photographs of steller spectra with the same result, we have reason to consider an independent origin probable.

The results so far obtained can only be regarded as preliminary, for with the improvements now being carried out in the telescope and spectroscope, and the much greater frequency of metallic eruptions as the maximum sun-spot period is approached, it is certainly to be hoped that many more lines will be photographed. The ultra-violet spectra of sun-spots have also been worked upon with some indications of success, and there will evidently be no lack of opportunity in the new and interesting fields thus opened to investigation.

London, August 13, 1891.

ART. L.—*Phonics of Auditoriums;* by EPHRAIM CUTTER, M.D., New York.

Reciprocation of sound.—When two strings of the violin family are tuned in unison, on causing one to sound "the air around it assumes a vibratory movement and this being propagated to the second string causes it to vibrate and emit the same sound or tone because each aerial pulse communicates motion to the second string, and as the movements of both are by the supposition isochronous each succeeding impulse augments the effect of the preceding and this phenomenon is termed the *reciprocation of sound.* Instances have occurred of persons who by modulating their voices, have excited vibrations in glasses so powerful as to overcome the cohesive attraction that held the particles together and consequently break them in pieces."—Bird. Nat. Phil.

An effect of air vibration is seen when a shrill whistle or infant's cry produces a flaring or upward projection of an ordinary gas or oil flame turned on just so as not to blaze. The jet shoots up in long digitations which cease to project when the tone stops.

Green in his History of the English People, vol. i, p. 67, writes of Dunstan the Ecclesiastical statesman: "One morning a lady summons him to her house to design a robe which she is embroidering, and as he bends with her maidens over their toil, his harp, hung upon the walls, sounds without mortal touch, tones which the excited ears around frame into a joyous antiphon." This would be unintelligible but for the "antiphon" which means that he sung and the harp responded.

A thousand years later a Yale student sounding a upper line bass clef 215 vibrations to the second, heard the A string of a 'cello in a distant corner of the room, face to walls, audibly antiphone with the same number of vibrations.

In the case of the two strings vibrating in unison within half an inch of each other it is easy to understand why one string would induce vibrations—from their proximity. But in the last example given there was a distance of 15 to 20 feet between the causal vocal tones and the string A. The other strings G 96·7, D 145 vibrations per second, would not respond when their tones were sung, showing a peculiarity of the A tone vibrations. C 64·5 vibration was too low for the voice. In a church when the pipe F of the subbass sounded the walls and floors would vibrate. Tunes performed in the key of F went with a vim perceptible even to listeners outside.

These examples suffice to show that even musical vibrations act more strongly on the ear and induce objects capable of the

same number of vibrations to produce the same musical tone. The size of the auditorium seems to govern this tone, which has been called the key note of the auditorium. Every room has its key note. No one will dispute that music in the key note of the auditorium is more effective than when it is not in that key. An opposite opinion clashes against the above facts. This being so with music, how is it with Phonics?

The differences between music and speech are much less than their joint properties. Both need normal vocal bands. Surgery shows this. A tumor exists which I removed from the vocal bands in 1866. For years before, the patient could not speak nor sing. She could only whisper. In 1891 she speaks and sings.

The same oripulations belong to speech and song. Song prolongs the basic vowel syllable sounds more than speech. These sounds are chiefly formed by the vocal bands alone as the writer since 1862 has shown to himself and others in his own larynx. Speech shortens these sounds. Speech is staccato in music with the rests left out.

The consonants are the same as a general rule in speech and song as to production. Speech and song have pitch, forte and piano.

From this—as Phonics in auditoriums are often a failure, i. e. people can't hear—is there not some remedy by making phonic laws conform to those of music? We think there is and for one thing would suggest *phonics in the key note of the auditorium.*

That is have the pitch of the speaker hold to the key note of the auditorium and vary only as a well regulated song, for example like "Annie Laurie."

The writer has seen this done successfully as follows, in

1. Cincinnati Music Hall, capacity 6000 people, key note F.
2. Prince Albert Memorial Town Hall, Leeds, England.
3. Section rooms of the X International Medical Congress, Berlin, 1890, and other places.

1, 2, 3, were of exceptional difficulty: 1, from its vast size. 2, elegant to the eye but hard for the ear. 3, were picture galleries never intended for the ear.

To find the key note.

Sing the natural scale slowly, *evenly and smoothly*, or play this scale on piano or organ similarly. The note which is most prominent will be the key note.

Those who control auditoriums may employ an expert to do this and post the result. For example, an auditorium of the City Hall at Saratoga Springs was thus tested 1890, and a notice was put up: "The key note of this hall is F."

September, 1891.

Art. LI.—*The Secular Variation of Latitudes;* by George C. Comstock.

[Read at the Washington Meeting of the American Association for the Advancement of Science.]

A possible secular change in the position of the terrestrial pole has long been a subject of discussion among astronomers and physicists, and the history of investigations made in this connection resembles in many respects that of similar researches upon stellar parallaxes. The early investigators expected to find, and announced the actual discovery of, very sensible variations of both kinds while their successors overturned their conclusions and traced their results back to errors of observation. Less than a decade ago a vigorous interest in the matter of latitudes seemed to be aroused by Fergola. A plan for systematic research was proposed and adopted and for a time we appeared to be on the eve of a repetition of the brilliant success attained by Bessel and Struve a half century ago in the determination of parallaxes. But Fergola's plan seems to have been abandoned without a trial and so far as astronomers are concerned these investigations have fallen into abeyance.

But an urgent demand for further research comes now from another quarter. The geologists having tried one by one the various hypotheses which have been advanced to account for the glacial periods have found them successively inadequate and untenable. In the inelegant but expressive language of one of these gentlemen they are "in a hole," and the only escape from the difficulty seems to be through the assumption that the terrestrial pole has wandered widely from its present position during recent geologic time.

I am no geologist, but since my attention was especially directed to the problem in hand by geologists, let me briefly summarize the case from their standpoint. The phenomena of erosion indicate that the last glacial epoch is separated from us in time by a period which is to be measured by thousands of years and probably not a very great number of thousands. At that epoch a certain portion of the earth's surface, including parts at least of Europe and North America, was buried in ice much as the continent of Greenland is now covered by an almost continuous glacier. Only recently has the area covered by the ice been delimited, but as a result of surveys made during the past five or six years it appears that the ancient glacier covered a region approximately bounded by a small circle of the earth whose pole lies somewhere in Greenland and whose angular radius is not far from 35°, *i. e.* the amount

of ice present in the northern hemisphere at the time of maximum glaciation was distributed in a manner very different from the present arrangement, and this different distribution will be fully explained by shifting the terrestrial pole from its present position to the center of Greenland. Opposed to this explanation, however, stands the common belief of astronomers that the position of the pole if not absolutely fixed is subject only to very inconsiderable changes.

To guard against any possible misapprehension let it be stated once for all that the questions here raised do not relate to the direction of the earth's axis in space, *i. e.* to the phenomena grouped under the names precession and nutation, but to the position of the points in which the rotation axis intersects the earth's surface.

If any such change in the position of the pole as is supposed above has occurred within recent geologic time it may be fairly presumed that some motion will still remain although nothing can be predicated *a priori* in regard to its amount or direction, and the problem which I have proposed to myself is to determine whether there is any such motion of the pole of sufficient magnitude to be shown by existing astronomical data.

Theoretically there are three classes of observations which may contribute to the solution of the problem: determinations of latitude, of azimuth and of longitude; but for the present at least only the first of these can furnish available data and the amount of satisfactory data of this kind is exceedingly small. I do not wish to enlarge here upon the inherent difficulties which stand in the way of determining a change in the latitude of a given station, but some consideration of them is necessary for the proper appreciation of the conclusions which are subsequently reached.

To take a concrete instance, the following determinations of latitude at Greenwich seem to indicate a progressive change in the position of that observatory:

Date.	Latitude.		Authority.
1693	51° 28′ 41″·7	Peters.	Flamsteed.
1751	38·72	Auwers.	Bradley.
1826	38·59	Pond.	Gr. Obs. 1834
1838	38·23	Airy.	Gr. Cat. 1860
1845	38·17	"	" " "
1855	38·15	"	" " "
1881	38·07	Christie.	Ten Year Catalogue.
1889	37·95	"	Annual Report.

We have here observations extending over a period of nearly two centuries during which the latitude appears to have diminished very appreciably, but I do not think that such a conclusion can properly be drawn from the data. Dr. Auwers informs me that Bradley's latitude may be anywhere from half a second to a second in error on account of uncertainties inherent in the data, errors of figure and division of the quadrant, errors of the tabular refraction, of the thermometer exposure, etc., and the same may probably be said of Pond's latitude while Flamsteed's is much inferior to either of these. If the several values of the latitude given above had all been derived with the same instrument and by the same method many of these errors would be eliminated from the differences, but in fact five different instruments were employed and the entire apparent variation of the latitude may fairly enough be ascribed to the undetermined errors affecting the results given by these instruments. The same facts obtain for much of the evidence sometimes cited to show a variation of latitude but they are not necessarily true of all of it.

To obtain a reliable indication of a change in latitude we must compare determinations made at a sufficient interval of time by the use of the same instrument and the same methods, or we must compare determinations made by methods which are practically free from systematic error, such as are furnished by the zenith telescope and the prime vertical transit. The results furnished by these instruments depend upon the adopted star places, but by using only observations of the same stars made at different epochs the change of latitude may be made to depend solely upon the proper motions of the stars and the residual error in these proper motions may be almost indefinitely diminished by increasing the number of stars employed. I assume that absolute determinations of latitude instead of being the only data from which a motion of the pole can be concluded are in the present state of practical astronomy decidedly inferior to differential determinations for this purpose. If these principles are applied to the data collected by Fergola and presented to the International Geodetic Association assembled at Rome they will be found to exclude nearly every case of supposed variation, although the general agreement of the data in indicating a progressive diminution of European latitudes must still remain a very striking fact.

Of all the cases in which an apparent variation of an absolute latitude is shown, the one least open to adverse criticism seems to be the discussion of the latitude of Pulkowa published by Nyrén, see *Die Polhöhe von Pulkowa* and *Observations de Poulkova*, vol. xiv. There are here two independent series of observations made with the vertical circle, the results of the

first of which, observations of Polaris, are shown in the following table:

Latitude of Pulkowa. Polaris Observations.

Date.	Observer.	Latitude.	No. of Obs.
1843	Peters.	59° 46′ 18″·73 ± 0″·013	371
1866	Gyldén.	18·65 ± ·014	236
1872·5	Nyrén.	18·50 ± ·014	155
1882·0	Nyrén.	18·40 ± ·010	184

The first three of these values are taken from Nyrén's paper on the latitude of Pulkowa, the last one is derived by myself from the data given at *p.* [50] of the volume of Pulkowa observations cited above, after correcting the individual results there given for the periodic variation of the latitude (Küstner) by means of the formula

$$-0''.26 \sin(\odot - 47°)$$

derived from meridian circle observations at the Washburn Observatory and confirmed by the special observations made at Berlin, Potsdam and Prague to determine the existence of a periodic variation. If this correction were omitted the value of the latitude for 1882·0 would be increased 0″·04. A graphical treatment of these data indicates an apparent diminution of the latitude amounting to 0″·005, six inches, per annum.

To this it has been objected by Bruns (V. J. S. vol. xxv, p. 15) that such a conclusion presupposes that the difference between the tabular refractions employed and the true refraction at the time of observation is the same for the several epochs and that this assumption requires confirmation. This confirmation is afforded by an investigation by Nyrén contained in vol. xiv above cited. From a discussion of the observations of 127 stars north of +45° declination, not including Polaris, treating the latitude and a correction to the assumed refraction as unknown quantities he finds for the epochs,

1846 (?) Latitude = 59° 46′ 18″·66
1866 " 18·546
Annual variation, −0″·006

This astonishingly close agreement between the results of two independent series of observations will probably suffice to establish the constancy of the refraction at Pulkowa during this period. The corrections to the tabular refractions for the two epochs differ by less than their probable errors.

There is available another series of Pulkowa observations by which to test the reality of the apparent change of latitude. I have compared the declinations of fourteen stars observed

with the prime vertical transit by both Oöm and Nyrén, the epochs of their respective observations being in the mean 1862 and 1881. Auwers has published proper motions for all of these stars save one for which I adopt Nyrén's value and comparing the declinations observed at the two epochs I find for the variation of the latitude between 1862 and 1881 $-0''\cdot12$, or Annual Variation $-0''\cdot006$, agreeing exactly with the result furnished by the vertical circle. I very much regret that I have not had access to the results of observations made with the prime vertical transit during the years 1840–1860 by W. Struve. I have, however, compared the declinations of the three stars most frequently observed during this period, which are discussed in Nyrén's paper *Bestimmung der Nutation der Erdachse*, with Nyrén's observations with the same instrument. From 375 observations of these stars at the mean epoch 1846 combined with 113 observations at the epoch 1881 using Auwers' proper motions I find

Annual variation of latitude, $-0''\cdot094$.

Each star shows a diminution of the latitude. These results derived from two different instruments and from different series of observations with these instruments seem to me inexplicable on any other hypothesis than that of a change of latitude and I adopt as the rate of variation at Pulkowa $-0''\cdot006$ per annum.

I know of no other European observatory at which a variation of latitude can be established in an equally satisfactory manner and the only one to which reference seems required is Königsberg. Two careful determinations of the latitude of the Repsold meridian circle have been made with the following results:

Date.	Observer.	Latitude.
1843·5	Bessel.	$54^\circ\ 42'\ 50''\cdot56 \pm 0''\cdot03$
1887·0	Rahts.	$50\cdot43 \pm \cdot04$

No investigation of a possible change in the amount of the refraction between the two epochs appears to have been made, but in spite of this defect the precision of the observations and the care with which the instrumental errors were investigated together with the Pulkowa results in regard to the refraction seem to entitle these determinations to some consideration. I therefore adopt for Königsberg

Annual variation of latitude , $-0''\cdot003$.

Turning now from European to American observatories we find a very different set of values. I shall first consider the latitude of the Washburn Observatory at Madison, Wis., as

determined from observations of fundamental stars made with the Repsold meridian circle. In the reduction of the observations the latitude is made to depend upon the declinations of these stars as given in the *Berliner Jahrbuch* and observations on opposite sides of the zenith were combined in such a way as to eliminate the errors of the instrument and of the refraction tables. The results of separate years are given in the following table:

Meridian circle latitudes of Madison.

Date.	Obs'r.	Latitude.	Ann. var.	Lat. 1890·0*
1883·8	T. 43° 4′	36″·45 ± 0″·14	+0″·06	36″·70
84·5	H. and C.	36·49 ± 0·04	+ ·05	36.72
85·5	H. C. and U.	36·54 ± 0·04	+ ·04	36·72
87·2	U. and L.	36·61 ± 0·04	+ ·11	36·72
88·6	B.	36·76 ± 0·03	+ ·05	36·82
89·6	B. and E.	36·81 ± 0·03	− ·11	36·83
90·2	B. and E.	36·74 ± 0·06		36·73

It should be said in regard to these values that the observations of each year except the first and last are distributed through the whole circuit of twenty-four hours of right ascension and are sufficiently numerous to furnish a good representation of the system of declinations adopted as fundamental. The latitudes thus derived are affected with whatever constant error inheres in the declination system and in the instrument itself, but since we are here concerned only with variations of latitude constant errors are of no consequence and we may therefore neglect the absolute value of the latitude and inquire what interpretation is to be placed upon its apparent annual increase.

I do not think that it will be seriously maintained by any competent critic that this variation is due to error in the star places for, the same stars being observed year after year, this would imply that the mean of the proper motions of some hundreds of fundamental stars is in error to the amount of 0″·06.

The variation may be due to accidental error of observation, but the uniform progression and the small probable errors of the results render this hypothesis somewhat improbable.

No correction for flexure has been applied to the observations and it may be supposed that the variation is due to a progressive change in the flexure constants. Nearly forty years ago W. Struve adopted this as the explanation of an apparent annual variation of 0″·06 in the latitude of Dorpat.

* Computed with the finally adopted elements of the motion of the pole.

But in the present case the sine flexure is eliminated by giving equal weight to the observations of stars on opposite sides of the zenith in the reduction of each night's work, and the cosine flexure is commonly supposed to be eliminated from the mean of observations made Circle W. and Circle E.

I know of no other reasonable hypothesis to adopt in this connection except that of an actual change in the latitude, but before coming to any conclusion it will be well to consider another set of latitude determinations which are available. The latitude of Madison was first determined in 1873 by officers of the U. S. Coast Survey, employing the Talcott method, and since that date five other determinations have been made by the same method. The final results of these determinations are contained in the following table:

Date.	Obs'r.	No. of Obs.	No. of Pairs.	Seconds of Lat.	Periodic Term.	Corrected Latitude.
1873·62	B.	60	12	$36''.24 \pm 0''.05$	$+0''.15$	$36''.39$
81·64	C.	26	16	$36.58 \pm .13$	$+ .17$	36·75
84·50	C. & H.	72	11	$36.98 \pm .08$	$- .03$	36·95
89·33	T.	84	15	$37.36 \pm .14$	$- .23$	37·13
90·50	T.	53	11	$37.17 \pm .09$	$- .03$	37·14
91·50	C.	49	13	$37.21 \pm .06$	$- .02$	37·19

The latitudes determined in 1884, '90 and '91 are from observation of substantially the same pairs of stars, the other latitudes are from other stars but all of the declinations employed have been taken either directly from the Berliner Jahrbuch or from a discussion of the data contained in modern catalogues of precision reduced by the application of systematic corrections to the system of Pub. XIV, *Astron. Gesell.* While the star places thus determined doubtless admit of further improvement, it seems to me highly improbable that any one of the above latitudes can be altered in this way by so much as $0''.1$ and they must therefore be considered as representing the relation of the latitude at the epochs of observation to the system of declinations of the Berliner Jahrbuch within the limits of the accidental error of observation and such systematic error as may affect determinations of this kind.

I have applied to the observed latitudes the correction for periodic variation

$$-0''.26 \sin (\odot + 73°)$$

and have obtained by a graphical treatment of the corrected results the

$$\text{Annual variation of latitude} = +0''.043$$

agreeing more closely than could be expected with the variation indicated by the meridian circle, while the several latitudes from which the annual variation is derived show the following astonishingly close agreement when reduced by it to a common epoch:

Date.	Latitude. 1890·0.	Weight.	*v.*
1873·6	43° 4′ 37″·10	4·0	−0″·03
81·6	37·11	0·6	− ·02
84·5	37·19	1·6	+ ·06
89·3	37·16	0·5	+ ·03
90·5	37·12	1·2	− ·01
91·5	37·13	2·8	·00

Since these two independent and dissimilar series of observations indicate the same variation of the latitude I conclude that this variation is real and I adopt for Madison

$$\text{Annual variation of latitude} = +0''\cdot043$$

If such a variation as this is actually in progress it must affect other latitudes and it should be recognized at every American observatory at which there is a series of latitude determinations extending over a considerable number of years. Unfortunately very few such series of observations have been published, the Naval Observatory at Washington being almost the only institution from which the requisite data can be obtained. The observations made here with the mural and transit circles have been discussed recently by Prof. Hall (A. J., No. 224) who concludes that "there is no proof of a secular change in the latitude." So far as this conclusion relates to the meridian instruments of the observatory I concur in it, but Prof. Hall includes in his discussion a comparison of the declinations of α Lyræ determined with the prime vertical transit in the years 1845, '48 and 1862–'67, and with reference to these observations I dissent from his conclusion and wish to present in some detail the evidence furnished by this instrument which on account of its extreme precision and its freedom from systematic error seems entitled to far more confidence than can properly be accorded to the meridian instruments. I must here acknowledge my indebtedness to the Superintendent of the Naval Observatory, Capt. F. W. McNair, U. S. N., who has placed at my disposal the manuscript results of unpublished observations made with this instrument in the years 1882–'84.

I have collated all the observations of α Lyræ, including fifty-eight made in the years 1846–'50, but omitted from Prof. Hall's data; have compared them with Auwers' declination of the star carried back to the epochs to which the observations

were reduced and from this comparison and a similar comparison with Boss's declination I have derived the following values of the latitude:

Epoch.	No. of Obs.	Seconds of Latitude.		Ann. Var.	
		Auwers.	Boss.	Auwers.	Boss.
1847·2	192	37″·26	37″·64		
				+0″·050	+0·031
1864·5	436	38·13	38·17		
				+ ·041	+ ·018
1883·5	123	38·90	38·51		

The progressive character of the results is here unmistakable and the Madison variation is confirmed. But in order that my conclusions may not be open to the objection of resting upon an assumed proper motion of a single star, I have derived a value of the latitude for the several epochs from all of the observations of fundamental stars (*Berliner Jahrbuch*) which are available for this purpose with the following result:

Epoch.	No. of Stars.	No. of Obs.	Seconds of Lat.	Ann. Var.
1847·0	41	461	37″·31 ± 0″·03	
				+0″·047
1864·5	1	436	38·13 ± ·06	
				+0·037
1883·5	9	306	38·83 ± .05	

Auwers' proper motions have been employed in this comparison, but it should be stated here that there is some uncertainty in regard to the proper motions employed by the observers in reducing the observed declinations to a mean equinox, since the printed volumes contain no indication of these. It is stated in connection with the mural circle observations that the proper motions there employed for this purpose were taken from the Nautical Almanac for 1848, and I have assumed that the same practice prevailed with the prime vertical transit and have corrected the printed results by the product of the difference between these proper motions and those of Auwers, multiplied by the time interval between the date of observation and the equinox to which the observations were reduced. There is probably a certain amount of error introduced by this process into the latitude for 1847 but its total amount must be exceedingly small since in no case were the observations reduced to an equinox more than five years removed from the date of observation.

The data furnished by the prime vertical transit may be presented in another form which eliminates the declinations of the stars and involves only their proper motions. There are nine stars common to the observations of 1847 and 1883 which are also contained in Auwers' Fundamental Catalog. A comparison of the corrections to Auwers' declinations furnished by the observations of 1847 and 1883 is contained in the

following table in the preparation of which I have assumed that the earlier observations were reduced with sufficiently accurate values of the proper motions to require no further correction. The error of this assumption will in some measure tend to counterbalance the error made above in the same connection.

Correction to Auwers' δ.

Star.	1847.	Obs.	1883.	Obs.	1847–1883.
$\varkappa$ Androm.	$+1''\cdot09$	17	$-0''\cdot14$	28	$+1''\cdot23$
Gr. 1450	$+1\cdot12$	2	$+0\cdot69$	24	$+0\cdot43$
10 Leo. Min.	$+1\cdot49$	2	$+0\cdot16$	10	$+1\cdot33$
31 Leo. Min.	$+1\cdot79$	5	$-0\cdot31$	23	$+2\cdot10$
17 H. Can. Ven.	$+1\cdot79$	3	$-0\cdot15$	13	$+1\cdot94$
π Herculis	$+1\cdot49$	5	$+0\cdot18$	28	$+1\cdot31$
Σ Herculis	$+1\cdot78$	3	$-0\cdot26$	19	$+2\cdot04$
α Lyræ	$+1\cdot52$	192	$-0\cdot10$	123	$+1\cdot62$
10 Lacertæ	$+1\cdot34$	8	$-0\cdot12$	38	$+1\cdot46$

This comparison may be interpreted as indicating either that the latitude of Washington changed to the amount of $1''\cdot5$ between 1847 and 1883 or that Auwers' proper motion of each of these nine stars is too great and that the mean value of this error is $0''\cdot041$. I do not at present see how to draw any other conclusion and of the two the former appears to me the more probable especially as it is confirmed by the Madison observations. I therefore adopt for Washington

Annual variation of latitude , $+0''\cdot042$

I have searched diligently for other American data to compare with the above but I have found nothing which certainly contravenes it and but little which confirms it. A comparison of the latitudes determined at Annapolis by Chauvenet in 1853 and by Brown in 1883 indicates an increase of the latitude by $1''\cdot0$ between these dates, but it is questionable if the observations are comparable.

The results at Cambridge are conflicting as is shown in the following table taken from vol. xvii of the Annals of the Harvard College Observatory, excepting the result for 1845 which I have derived from a rediscussion of the original data contained in Peirce's memoir on the Latitude of Cambridge.

Date.	Latitude.	Method Employed.
1845·0	$42° 22' 47''\cdot00 \pm 0''\cdot19$	Prime Vertical Transit.
55·8	$47\cdot61 \pm \cdot08$	Zenith Telescope.
85·8	$47\cdot64 \pm \cdot02$	Almucantar.

In my judgment no conclusion can be drawn from these numbers until the relative errors of the several methods have been

more closely investigated than has yet been done. For the present the only available data seems to be contained in the following table:

Station.	Longitude.	Ann. Var. of ϕ.	Weight	No. of Determin's.	Comput'd Ann. Var.
Pulkowa	−30°·3	−0″·006	4	3	−0″·007
Königsberg	−20·5	−0·003	1	1	−0·000
Washington	+77·0	+0·042	4	1	+0·044
Madison	+89·4	+0·043	4	2	+0·041

The longitudes are reckoned from Greenwich.

I have made a least square solution of these data to determine the most probable direction and amount of motion of the pole and find a motion of 0″·044 along the meridian 69° west of Greenwich. The last column of the table above contains the values of the annual variation at the several stations computed from these elements.

If the elements of the motion of the pole thus derived are even a rough approximation to the truth they furnish valuable indications of the methods by which our knowledge may be extended. In the first place European observatories cannot be expected to show any considerable change of latitude. Observations made there will be chiefly valuable for determining the direction of motion of the pole and for this purpose a careful comparison of the older latitudes with modern determinations is much to be desired. In particular the latitude determinations made at Dorpat by W. Struve in 1824 and 1827 with the meridian circle and prime vertical transit are for this purpose probably the most valuable data not yet utilized. I have endeavored to compare these with similar modern determinations by Schwarz and Renz but the printed results of the later determinations, at least so far as I have access to them, do not furnish sufficient data for the purpose. In America the older latitudes of the Coast Survey could very profitably be rediscussed and compared with redeterminations at such stations as can now be identified. A redetermination of the latitude of Cambridge with both the prime vertical transit and the zenith telescope seems especially desirable and the Asiatic stations occupied by the American Transit of Venus parties in 1874 can be made to furnish most valuable data, since their latitudes should now be three quarters of a second less than in 1874.

I wish now to consider briefly a plan for the systematic investigation of the motion of the pole. For the present it seems best not to attempt the absolute determination of latitudes for this purpose on account of their great liability to systematic error but rather to rely upon differential methods.

These methods as commonly applied require an accurate knowledge of the declinations and proper motions of the stars but it is perfectly feasible to eliminate both declinations and proper motions and leave the resulting variation of latitude almost if not quite free from systematic error. To illustrate, suppose two stations to be selected as nearly as possible on the same parallel of latitude, one in longitude 70° west of Greenwich and the other 110° east and let the latitudes of the stations be simultaneously determined by zenith telescope observations of the same pairs of stars. The difference of the latitudes of the stations thus determined is entirely independent of the star places, and I know of no source of systematic error by which this difference can be affected except possible personal peculiarities of the observers which can be eliminated by an interchange of observers if this should be thought desirable. The periodic variation of the latitude would be eliminated from the mean of observations made at epochs six months apart. An annual motion of the pole of 0″·045 will alter the difference of latitude of these stations by twice this amount per year giving a change in the difference of latitude amounting to 1″ in eleven years, a quantity which cannot possibly escape careful observations with the zenith telescope or prime vertical transit. If similar observations be conducted near the meridian 20° east of Greenwich they will furnish the best attainable data for determining the direction of motion of the pole. The execution of this program, which can be effected within a dozen years, will add more to our knowledge of the variation, or possible permanence, of terrestrial latitudes than can be furnished by all the astronomical observations that have hitherto been made. By a proper selection of stations it will even be possible within a year or two to test the results above obtained. The following pairs of stations approximately satisfy the conditions above indicated and in addition possess the great advantage that at each one of them a good value of the latitude was determined by the Talcott method prior to 1875:

Vladivostok,	Lat. 43° 6′·6	Peking,	Lat. 39° 54′·3
Madison, Wis.	43 4·6	Columbus. O.	39 57·7
Nagasaki,	Lat. 32° 43′·4		
Macon, Ga.	32 50·4		
San Diego, Cal.	32 43·1		

If these stations can now be reoccupied the simultaneous determination of latitudes at the two stations composing a group will furnish the beginning of the program above indicated while the latitudes thus derived will be immediately

available for comparison with the earlier determinations. I know no reason to suppose that the determinations of latitude already made at the other stations are less precise than that at Madison and a rediscussion of this determination has shown that by the aid of improved star places the latitude referred to Auwers' declination system is determined for the epoch 1873 with a probable error of 0″·05. If the same degree of precision obtains at the other stations a new set of determinations in 1892 would furnish for a single pair of stations a value of the annual motion of the pole with a probable error of only 0″·003.

But little difficulty will be experienced in securing new determinations at the American stations. I will myself become responsible for the observations at Madison, and it is probable that upon a proper presentation of the case being made to the Superintendent of the Coast and Geodetic Survey the observations at Columbus and Macon or San Diego will be undertaken by that organization. To secure the reoccupation of the Asiatic stations, however, is a very different matter, for which concerted action of some kind will probably be necessary, and it is with a view to securing such action that I present this paper to the Section for discussion.

ART. LII.—*On the Capture of Comets by Planets, especially their Capture by Jupiter;* by H. A. NEWTON.

[Continued from p. 199, Sept., 1891.]

30. IF there are assumed to be n comets equably distributed in each unit of the space near and through which a planet is moving, and if these comets are all assumed to be moving in parabolas about the sun with the velocity v, having also their directions of motion equably distributed, then the number that are moving from quits lying within an element $d\mathrm{S}$ of the surface of the celestial sphere will be $\frac{n d\mathrm{S}}{4\pi}$. Let v_0 be the common velocity of these comets relative to the planet. Then suppose that a spherical surface S′ is described with a radius r' about the planet as center; r' being small relative to the sun's distance, yet not so small as to forbid the omission of the planet's perturbing action so long as the comet is without the surface S′. In each unit of time out of these comets directed from the element $d\mathrm{S}$ of the celestial sphere there would pass nearer than r' to the planet $n\frac{d\mathrm{S}}{4\pi}\cdot \pi r'^2 v_0 = \frac{1}{4} n v_0 r'^2\, d\mathrm{S}$

comets if unperturbed. Evidently an equal number cross the surface S′ entering the sphere in each unit of time.

If now ω be the angle which the comet's unperturbed motion is making with the planet's motion, and if v_1 or its equal $v/\sqrt{2}$, be the planet's velocity in its orbit about the sun, then $v_0^2 = \frac{1}{2}v^2[3-2\sqrt{2}\cos\omega]$. The element dS may be taken to be the elemental zone between the two small circles whose common pole is the planet's quit, and whose distances from the planet's quit are ω and $\omega+d\omega$. Then $d\text{S} = 2\pi\sin\omega\, d\omega$. The number of comets entering S′ in a unit of time with quits within that elemental zone will be

$$\tfrac{1}{4}nv_0r'^2 \times 2\pi\sin\omega\, d\omega = \frac{\pi nvr'^2}{2\sqrt{2}}(3-2\sqrt{2}\cos\omega)^{\frac{1}{2}}\sin\omega\, d\omega.$$

The integral of this,

$$\frac{\pi nvr'^2}{2\sqrt{2}}\int_0^{\pi}(3-2\sqrt{2}\cos\omega)^{\frac{1}{2}}\sin\omega\, d\omega = \tfrac{4}{6}\pi nvr'^2,$$

expresses the total number of comets that, under the hypotheses that have been made, would in a unit of time enter the sphere S′.

31. If we compare the two expressions obtained in Arts. 27 and 30 we find that the number of comets which, in a given period of time come nearer to the sun than r is to the number that (unperturbed) come nearer to the planet than r' as $6r^2$ is to $7r'^2$. The factor $\frac{4}{6}$ expresses the increase of numbers caused by the planet's motion in its circular orbit. The value of r', as has been said, must not be too small, nor yet must it be very large.

32. In order to determine the number N of comets which in a unit of time will have their periodic times reduced below a given period we may make use of the isergonal curves represented in Figs. 2–18. Although the diagrams were not constructed to exhibit the motions of the bodies, yet they may be utilized for that purpose. Let OH be the tangent to the planet's orbit, O the place of the planet considered at rest, and let the plane HOE contain the shortest line d between the two orbits. This d will be the abscissa of the point at which the comet's unperturbed orbit will cut the plane. The ordinate of the same point, produced if necessary, will be the projection of the comet's path upon the plane HOE, and the comet's path makes with the plane the angle θ. The velocity of the comet perpendicular to the plane will be $v_0\sin\theta$. By reason of the hypothesis that the comets are equably distributed, the points of intersection with the plane HOE will be equably distributed over the plane. Hence the number of

comets whose quits are in the element dS of the celestial sphere and that will pass the planet in a unit of time in such a way as to have their periodic times reduced below a given period will be equal to the area inclosed in the corresponding isergonal curve multiplied by the velocity perpendicular to the plane, $v_0 \sin\theta$, and by the factor $\frac{ndS}{4\pi}$. If @ is the semi-major axis of the orbit for the limiting periodic time, the area of the corresponding isergonal curve will be (Art. 17).

$$\frac{\pi}{\sin\theta}\left(\frac{4m^2@^2}{s^2} - \left(\frac{2m@\cos\theta}{s} - \frac{mr}{s^2}\right)^2\right).$$

For dS we may, as before, take $2\pi \sin\omega\, d\omega$, and we shall then have

$$\mathrm{N} = \frac{\pi n}{2}\int v_0 \sin\omega\left[\frac{4m^2@^2}{s^2} - \left(\frac{2m@\cos\theta}{s} - \frac{mr}{s^2}\right)^2\right]d\omega.$$

The integration must extend through the positive values of the quantity in square brackets beginning at $\omega = 0$. [In case $\omega = 0$ gives a negative value for the quantity in square brackets we must integrate between the two values of ω corresponding to the zero value of the bracketed quantity.] We may make S the independent variable by the equations $sds = \sqrt{2}\sin\omega\, d\omega$, $v_0\sqrt{2} = sv$, and $2s\cos\theta = 1 - s^2$.

These give:

$$\mathrm{N} = \tfrac{1}{4}\pi n m^2 v\int\left[4@^2 - \left(\frac{@ - r - @s^2}{s}\right)^2\right]ds.$$

33. If now we require the number of comets which in each unit of time shall pass the planet in such way as that they shall have after the passage respectively less than one-half, once, three-halves, and twice, the planet's period of revolution, we may place $@ = r\mathrm{T}^{\frac{2}{3}}$, and make T equal successively to $\frac{1}{2}$, 1, $\frac{3}{2}$, and 2, and compute in each case the value of N as given in the last article. The results are found to be $\pi n m^2 r^2 v$ multiplied severally by the coefficients 0·139, 0·925, 1·875, and 2·943.

34. By comparing the results of Arts. 27 and 33, and making the assumptions of Art. 26, we have the proposition, that *the number of comets which in a given period of time pass their perihelia nearer to the sun than a given planet, is to the number of comets whose periodic times are reduced by the perturbing action of the planet so as to be less severally than one-half, once, three halves, and twice, the periodic time of the planet, as unity is to the square of the mass of the planet multiplied severally by* 0·139, 0·925, 1·876 *and* 2·943.

35. If Jupiter is the planet, $m = \frac{1}{1050}$, and we may express these ratios as

$$1\ 000\ 000\ 000 : 126 : 839 : 1701 : 2670.$$

That is, assuming the hypotheses of Art. 26, and regarding the planet as without dimension so as to intercept any comets, *if in a given period of time a thousand million comets come in parabolic orbits nearer to the sun than Jupiter,* 126 *of them will have their orbits changed into ellipses with periodic times less than one-half that of Jupiter;* 839 *of them will have their orbits changed into ellipses with periodic times less than that of Jupiter;* 1701 *of them will have their orbits changed into ellipses with periodic times less than once and a half times that of Jupiter; and* 2670 *of them will have their orbits changed into ellipses with periodic times less than twice that of Jupiter.*

36. Another and perhaps a more important inquiry is this, what effect have the perturbations of the planet in bringing or not bringing the comets to move in the same direction that the planet is moving after the comets have by perturbation had their periodic times largely reduced. For simplicity and as a special example I shall consider the action of Jupiter only, and also only his action upon those comets whose periodic times are reduced to be less than Jupiter's period, the original orbits of the comets being parabolic. In other words, how many of the 839 comets which are reduced (Art. 35,) to have periodic times less than Jupiter's period will after perturbation have goals distant less than 15°, 30°, 45°, etc., severally from Jupiter's goal?

37. Let BA, Fig. 19, be drawn to represent v_1 and CA to represent $v_1\sqrt{2}$. With A as a center and AB and AC as radii describe the semicircumferences BLO and CHG. Let the angle BAH be made equal to ω and BH be drawn; then HA will represent the comet's velocity about the sun, BA the planets velocity about the sun, and therefore HB the comet's velocity v_0 in its orbit about the planet before perturbation. About B as center describe the semicircumference KHT. Since the relative velocity after as well as before perturbation is equal to HB, therefore the velocity of the comet about the sun after perturbation will evidently be represented by a line drawn from some point in the semicircumference KHT to A. If the velocity is increased the new velocity will be represented by a line to A from some point in the arc KH, if diminished by a line to A from some point in the arc HT. If the new velocity is less than the planet's velocity, and so the new cometic period less than the planet's period, the new velocity will be represented by a line to A from some point in the arc ET.

If in a diagram constructed for $\omega = \text{BAH}$ the isergonal curve be drawn for $@ = r$, those comets for which d and h represent points within that isergonal curve will after perturbation have velocities represented by lines drawn from points in ET to A, while comets for which d and h represent points outside that isergonal curve will after perturbation have directions of motion represented by lines drawn to A from points in EHK.

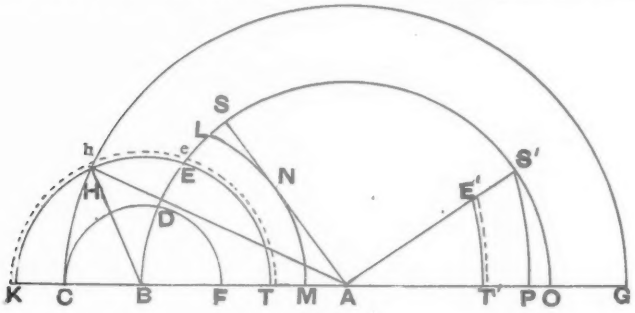


Fig. 19.

The number of comets having motions represented by lines to A from points in ET will be proportional to the area of the isergonal curve $@ = r$. Let the angle BAS represent a limiting value ω'' of distance of quits of comets from Jupiter's quit after perturbation. The comets which are thus limited and at the same time have $@ < r$ will be moving in lines directed to A from points in the area bounded by the straight lines SA and AF, and the arcs FD and DS. Let ω receive an increment $d\omega = \text{H}h$ and let a new semicircumference be drawn with Bh as radius. To the elemental arc Hh will correspond the elemental area along the semicircumference KET. If ET lies wholly in SAFD the number of comets that pass the planet in a unit of time having initial angles of direction with Jupiter's motion between ω and $\omega + d\omega$ will be equal to the area of the isergonal curve for $@ = r$ multiplied by the elemental number $\frac{1}{2}n \sin \omega d\omega$, and by the relative velocity $v_0 \sin \theta$ of the comet perpendicular to the isergonal area. If the area of the isergonal curve be represented by $\Phi s^2 \sin \theta$, then this product will be

$$\frac{\Phi}{s^2 \sin \theta} \cdot v_0 \sin \theta \cdot \frac{n \sin \omega d\omega}{2} = \frac{nv}{4} \Phi ds.$$

since $\sqrt{2} v_0 = sv$, and $\sqrt{2} \sin \omega d\omega = s ds$.

38. This expresses the elemental number of comets corresponding to the elemental area Te. The integral of this expression, that is, $\frac{1}{4} nv \int \Phi ds$, so taken as to cover the area

AFDS will give the number of comets which in a unit of time will pass the planet in such a way as to have $@ < r$ and $\omega' <$ BAS. When the elemental area does not extend from the arc DS to the line BA, the area of another appropriate isergonal curve is to be used in determining Φ.

By Art. 17 we have

$$\Phi = \pi m^2 \left[4@^2 - \left(\frac{@ - r - @s^2}{s} \right)^2 \right].$$

For the elemental areas of the surface AFDS which end on the arc DS we make $@ = r$, and let Φ_0 be the resulting value of Φ; then $\Phi_0 = \pi m^2 r^2 (4 - s^2)$.

For elemental areas that end on the radius AS the values of @ on that line are functions of s. To compute them let v' be the comet's velocity in its orbit about the sun, and hence equal to the distance of the point on AS from A; then, by the triangle of velocities

$$v_1^2 + v'^2 - 2v'v_1 \cos \omega'' = v_0^2 = s^2 v_1^2.$$

Again by the laws of gravitation,

$$v'^2 = \left(2 - \frac{r}{@} \right) v_1^2.$$

Hence
$$s^2 = 3 - \frac{r}{@} - 2\sqrt{2 - \frac{r}{@}} \cos \omega'',$$

or
$$\frac{@}{r} = \frac{3 - s^2 - 2\cos^2 \omega'' \pm 2\cos \omega'' (s^2 - \sin^2 \omega'')^{\frac{1}{2}}}{9 - 8\cos^2 \omega'' - 6s^2 + s^4}.$$

Let Φ' and Φ'' be the two values of Φ obtained by substituting in Φ these values of @, Φ'' representing the value for the point nearer to A.

39. If $\omega'' = 90°$, and therefore $\cos \omega'' = 0$, we have along the limiting line, the two values of @ equal, hence

$$\frac{@}{r} = \frac{1}{3 - s^2}, \text{ and } \Phi' = \frac{s^2 - 1}{s^2 (3 - s^2)^2},$$

so that the number of comets having quits less than 90° from Jupiter's quit and $@ < r$ is

$$\frac{nv}{4} \int_{\sqrt{2}-1}^{\sqrt{2}} \Phi_0 ds - \frac{nv}{4} \int_1^{\sqrt{2}} \Phi' ds = \frac{\pi n v m^2 r^2}{4} \left[\int_{\sqrt{2}-1}^{\sqrt{2}} (4 - s^2) ds - 4 \int_1^{\sqrt{2}} \frac{(s^2 - 1) ds}{s^2 (3 - s^2)} \right]$$

$$= \frac{\pi n v m^2 r^2}{12} (7 + \sqrt{2}) = .7012 \, \pi n v m^2 r^2.$$

Since the whole number of such comets is (Art. 33) equal to $.925 \, \pi n v m^2 r^2$, the number of comets the distance of whose quits

from Jupiter's quit is between 90° and 180° is ·224 πnvm^2r^2. The number of the comets for which $@<r$ that have inclinations to the ecliptic less than 90° is to the number that have inclinations greater than 90° as 701 is to 224. *Of the* 839 *comets spoken of in Art.* 36, 203 *will after perturbation have retrograde motions, and* 636 *will have direct motions.*

40. If ω'' is less than 90° the expression to be integrated in order to cover the area SAFD will be

$$\int_{\sqrt{2}-1}^{\sin\omega''} \Phi_0 ds + \int_{\sin\omega''}^{2\sin\frac{1}{2}\omega''} (\Phi_0 - \Phi')\, ds + \int_{\sin\omega''}^{1} \Phi'' ds.$$

If ω'' is greater than 90° the corresponding expression becomes

$$\int_{\sqrt{2}-1}^{2\sin\frac{1}{2}\omega''} \Phi_0 ds - \int_{1}^{2\sin\frac{1}{2}\omega''} \Phi''\, ds.$$

As the value of @ introduces into Φ' and Φ'' only one radical in s, and that a radical of the second degree, these integrations are possible. Finite summation is however more convenient. Computing the values for each interval of 15° we construct the following table. The first column indicates the interval in values of ω''; the second column gives that coefficient of $\frac{1}{4}\pi nvm^2r^2$ that must be used to obtain the number of comets which in a unit of time will pass perihelion nearer than Jupiter's distance to the sun, shall also have their periodic times reduced to be less than Jupiter's period, and shall also leave Jupiter's vicinity so that the distance between the quits of the two bodies is between the two values in column I; the third column indicates the distribution of the 839 comets of Art. 36 through the twelve zones.

TABLE III.

Limiting values of ω''.	Coefficient of $\frac{1}{4}\pi nvm^2r^2$.	No. out of 839 comets.
From 0° to 15°	26	6
From 15° to 30°	401	91
From 30° to 45°	751	170
From 45° to 60°	670	152
From 60° to 75°	548	124
From 75° to 90°	443	101
From 90° to 105°	296	67
From 105° to 120°	235	53
From 120° to 135°	162	37
From 135° to 150°	99	23
From 150° to 165°	50	11
From 165° to 180°	16	4

We see also from the last column of this table that of the 839 comets under consideration 267 have quits less than 45°

from Jupiter's quit, while only 38 of them have quits within 45° of Jupiter's goal.

41. Table III gives the distribution of the comet quits relative to Jupiter's quit. It may also be used to determine how many of the comets whose orbits are thus changed shall have an inclination to the plane of Jupiter's orbit less than a given angle.

Let the angle be 30°. Let Q be Jupiter's quit on the celestial sphere, Q′ the comet's quit and S the sun's position as seen from Jupiter. Then in the triangle QQ′S put ω'' for QQ′ the distance of the quits. The side QS = 90°, and QSQ′ will be the inclination of the orbits. Represent this angle by i and the angle Q′QS by η. Then $\sin \eta = \cot \omega'' \cot i$.

Let two small circles be drawn about Q at distances ω'' and $\omega''+d\omega''$ then if $d\omega''$ be made 15° the numbers in the second or third columns of table III indicate how many quits are in the several zones of 15° on the celestial sphere. These may be distributed at smaller intervals than 15° by known processes. All the quits that lie in the lune between two semicircles drawn through S so as to make angles of 30° with QS will evidently have orbits inclined less than 30° to Jupiter's orbit. From $\omega'' = 0$ to $\omega'' = 30°$ all the quits are included in the lune. From $\omega'' = 30°$ to $\omega'' = 90°$ we compute η from the equation $\sin \eta = \cot \omega'' \cot 30°$; then the portion of the quits in any elemental zone that fall in the lune is to the whole number of quits in that elemental zone as this value of η is to 90°. These may be summed by finite summation, and the result is that among the 839 comets 257 would move in orbits inclined less than 30° to the orbit of Jupiter

42. If a like summation be made for the equal lune that contains Jupiter's goal we find 51 to be the number out of the 839 comets which move in orbits inclined more than 150° to Jupiter's orbit. That is, *somewhat more than five times as many of these comets move in direct orbits inclined less than 30° to Jupiter's orbit as move in retrograde orbits inclined less than 30° to Jupiter's orbit.*

43. The comet has been thus far considered as approaching Jupiter while moving in a parabolic orbit about the sun. If the comet however is moving in any other orbit, and it passes near to the planet, the result of the planet's perturbing action will in general be quite similar to the result when the orbit is parabolic, the other circumstances of the approach being assumed to be alike in the two cases.

44. These are perturbations during one transit past the planet. But the comet, unless the orbit is further changed by another planet, must return at each revolution to the place where it

encountered Jupiter. At some time Jupiter will be nigh that place nearly at the same time as the comet, and the comet will suffer a new, and perhaps a large perturbation. Its period will again be changed, being shortened or lengthened according as the comet passes before or behind the planet. This process will be repeated again and again, since after any number of encounters the new orbit of the comet will still pass near to the orbit of the planet.

This repeated action makes it possible to have an orbit shortened in period by several passages near to Jupiter instead of its being done at one passage. A much larger proportion of comets than 839 out of 1,000,000,000 might therefore have their periodic times reduced below the period of Jupiter.

45. If the comet's orbit is largely inclined to the ecliptic and hence its motion makes a large angle with that of Jupiter the diagrams figs. 10–18 show that there is nearly an even chance that the velocity will be increased or diminished. A considerable fractional part of the whole number of such comets will at each passage be thrown out of the solar system altogether, or thrown into such long orbits that they will return only at very great intervals of time. This class of comets cannot be therefore regarded as permanent members of the family of short period comets, except such of them as happen to come so near to other planets as to have their orbits changed in such wise that they do not have thereafter the near approach to Jupiter's orbit. But when an orbit is greatly inclined to the plane of the solar system the comet passes through the plane in general at a considerable angle and the chance of coming close to another planet is relatively small.

46. On the other hand all the comets which after perturbation are moving in orbits somewhat but not greatly inclined to the ecliptic are liable to meet, in fact are sooner or later almost certain to meet other planets in such a way as to suffer perturbations that will prevent future close encounters with Jupiter. After such changes those comets must be regarded as tolerably permanent members of the solar system.

47. Comets that have motions not greatly inclined to Jupiter's motion are, as figs. 2 and 4 show, more likely in subsequent passages near to Jupiter to have their periodic times shortened than lengthened. On the contrary those passing in nearly opposite direction to Jupiter's motion will as figs. 3, 5 and 7 show, be much more likely to have their periods lengthened than shortened.

All these causes combine and work together to the one end that those comets which are changed by the perturbing action of Jupiter, or other planets, from parabolic orbits of every possible inclination to the ecliptic into short period ellipses

and become permanent members of the solar system, will as a rule (but with exceptions) move in orbits of moderate inclination to the ecliptic, and with direct motions.

We know as a fact that most short period comets do move in orbits having small inclinations and direct motions, while long period and parabolic comets move at all possible inclinations to the ecliptic. If the short period comets have been changed by Jupiter and other planets from parabolic orbits, the preceding investigation shows why their orbits have now small inclinations to the ecliptic, and the comets themselves have direct motions.

ART. LIII.—*Distribution of Titanic Oxide upon the surface of the Earth;* by F. P. DUNNINGTON, University of Virginia, Charlottesville, Va.

AT the Ann Arbor meeting of the Association for the Advancement of Science in 1885, I read a short paper* which considered the occurrence of titanic oxide in considerable amount in certain soil of Albemarle Co., Va.; and in an article published† in 1888, by Mr. J. F. McCaleb and myself, we presented estimations of this substance in sixteen specimens of soil from scattered points of the United States.

In view of the unfrequent mention of this element as a constituent of rocks and the very rare mention of its occurrence in soils, I have endeavored to secure samples of soil and some rocks from points scattered over the earth's surface; and, including the before mentioned sixteen, I herewith present the results of examining eighty specimens.

The method employed in the recent determinations is the following: weigh into a platinum crucible one gram of the powdered sample, ignite, again weigh, then moisten with water and add 2 or 3 c.c. of hydrofluoric acid,‡ gradually heat to dryness, add about 7 grams of sodium acid sulphate, gradually heat to low redness for 1 or 2 hours, cool, digest in 5 per cent diluted sulphuric acid for several hours, filter, to filtrate§ add about 1 c.c. of hydrogen peroxide solution and compare the color so produced with one similarly obtained from a standard solution of titanic oxide.

* Proc. A. A. A. S., xxxiv, 132. † American Chem. Jour., x, 36.

‡ This acid was used before seeing the article of Dr. Noyes in Jour. Anal. Chem., v, 39.

§ Method of A. Weller: Berichte d. deutsch. chem. Gesell., xv, 2592.

To present a more satisfactory comparison with the amount of titanic oxide in the rocks, the percentage on the ignited soil is given together with that on the air-dried soil.

Nos. (1) to (12) are all from Albemarle Co, Va. (1) is dark red clay, from Carter's mountain, farm of Rev. J. T. Randolph being the soil from which was formed a fulgerite (?) which first drew my attention to this occurrence of titanic oxide. (2), deep red clay, one mile south of (1). (3), red clay, one mile north of (1). (4), red clay, one-half mile west of (1). (5), light red sand, one mile northwest of (1). (6), red bottom soil, one and one-half miles northwest of (1). (7), white micaceous soil, near McCormick Observatory, University Va., and three miles west of (1). (8), near chemical laboratory of University Va. (9), mica schist, one-half mile north of (8). (10), deep red clay, ten miles southwest of (1). (11), red clay ten miles west of (1). (12), Diorite, the rock which is most common in the above locality.

Nos. (13) to (17) are from other points in Virginia: No. (13), is deep red clay from farm of Mr. J. Shelton, Lowesville, Nelson Co. No. (14) a dark gray clay from swamp on Rappahannock River in Stafford Co. No. (15), a gray sandy loam, near Williamsburg, James City Co. No. (16), a yellow clay, per Mr. F. P. Brent, Onancock Creek, Accomac Co. No. (17), white sea sand, from Virginia Beach, Princess Anne Co. The percentage of titanic oxide found in these respectively is as follows:

	Air-dried.		Air-dried.		Air-dried.	Ignited.
(1)	5·42	(7)	0·77	(13)	1·87	
(2)	1·45	(8)	2·86	(14)	0·88	
(3)	2·73	(9)	1·14	(15)	0·49	0·50
(4)	2·73	(10)	1·86	(16)	0·80	0·84
(5)	0·33	(11)	1·51	(17)	0·07	0·07
(6)	1·73	(12)	1·15	Average	1·57	

Nos. (18) to (40) are from other portions of the United States. No. (18), a light brown loam, per Dr. A. C. Hopkins, Charlestown, W. Va. No. (19), a gray loam, per Mr. J. W. Rinehart, Foote, Mineral Co., W. Va. No. (20), pale red loam, a "limestone soil" per Mr. C. C. Councilman, Worthington's valley, Baltimore Co., Md. No. (21), a gray yellow loam, per Dr. Simon Gage, Cornell University, N. Y. No. (22), a gritty yellow loam, per Dr. F. P. Venable, Chapel Hill, N. C. No. (23), a light yellow clay, 1 foot deep, per Mr. R. M. Cooper, near Black River, Sumter Co., S. C. No. (24) a gray clay per Dr. P. S. Baker, over Carboniferous Limestone, Greencastle,

Ind. No. (25) a gray clay, per Dr. W. A. Noyes,* Terra Haute, Ind. No. (26), a deep orange clay sub-soil per Prof. C. E. Wait, Knoxville, Tenn. No. (27), a pinkish china clay from a 10-foot seam, and No. (28), a coarse gray clay from an 18 foot seam, both per Mr. W. R. Searcy, Tuscaloosa, Ala. No. (29), a heavy gray clay, per Mr. A. P. Wright, River bottom soil, Bolivar Co., Miss. No. (30), light red surface loam and No. (31), a gray sub-soil, both per Mr. Thos. Dunnington, Pine Bluff, Ark. No. (32), a brown clay, 6 feet deep, per Prof. W. H. Echols, Rolla, Mo. No. (33), a pale gray loam, per Dr. F. W. Traphagen, Deer Lodge, Montana. No. (34), a gray alkaline soil, from Truckee Valley, Nevada. No. (35), a yellow surface clay, per Dr. Masser, Los Angeles, Cal. No. (36), a brown clay, 3 feet deep, per Prof. H. E. Storrs, Los Angeles, Cal. Nos. (37) to (40) were sent by Prof. E. W. Hilgard, Berkeley, Cal. No. (37), upland red loam Station No. 1226, from Yuba River near Smartsville. No. (38), yellow gray Mesa soil, Station No. 1281, from Chino Ranch Station, San Bernardino Co. No. (39), "Red Mountain Land," Station No. 188, from a vineyard in Sonora Co. No. (40), a red loam, Station No. 1110, Thermolite Colony, Butte Co.

The percentage of titanic oxide found in these respectively is as follows:

	Air-dried.	Ignited.		Air-dried.	Ignited.		Air-dried.	Ignited.
(18)	0·83	0·88	(26)	0·46	0·50	(34)	0·57	
(19)	0·88	0·98	(27)	1·01	1·12	(35)	0·72	0·82
(20)	1·17	1·26	(28)	0·67	0·76	(36)	0·49	0·53
(21)	0·55	0·58	(29)	0·46	0·61	(37)	0·77	0·85
(22)	0·49	0·55	(30)	0·52	0·62	(38)	0·72	0·75
(23)	0·57	0·61	(31)	0·60	0·62	(39)	4·93	6·05
(24)	0·71	0·76	(32)	0·57	0·65	(40)	0·90	0·97
(25)	0·58	0·62	(33)	0·44	0·50	Average	0·85	0·98

Nos. (41) to (45) are from Oceanica and Asia. Nos. (41) to (45) were sent by Prof. A. B. Lyons, Oahu College, Hawaii, Sandwich Islands. No. (41), a dark brown loam. No. (42), a yellow brown loam. No. (43), a yellow brown loam. No. (44), a brown clay. No. (45), a gray brown loam. No. (46), a light gray china clay and No. (47), a gray china clay, both per Miss Mildred Page, Tokio, Japan. No. (48), a piece of a gray brick from the Great Wall of China, per Rev. Collins Denny. No. (49), a pink clay and No. (50), a yellow loam subsoil from the bank of the Yellow River, and No. (51) a fine yellow silt from the old bank of the Yellow River. The three last specimens were sent by Dr. Edgar Woods, Tsing-Kiang-Pu, China. No. (52), light red pottery, from Kurrachee, Sind, India. No.

* Dr. Noyes writes that he has recently found from ·5 to 4· per cent of titanic oxide in a number of minerals from Arkansas.

(53), dark brown crucible clay and No. (54) red furnace clay; both from Tumkur, India. The three last specimens were sent by H. B. M's Secretary for India. No. (55), gray loam from the shore of the Sea of Galilee, Palestine, per Rev. Collins Denny, of Vanderbilt University.

The percentage of titanic oxide found in these respectively is given below, and in making an average the specimens (41) to (45) are counted as one.

	Air-dried.	Ignited.		Air-dried.	Ignited.		Air-dried.	Ignited.
(41)	4·43	5·25	(47)	0·40	0·50	(53)	0·62	0·73
(42)	2·40	3·37	(48)	0·55	0·55	(54)	0·28	0·30
(43)	2·25	3·11	(49)	0·58	0·68	(55)	1·80 (?)	1·90
(44)	4·00	4·64	(50)	0·60	0·65	Average	0·90	1·18
(45)	2·78	3·37	(51)	0·54	0·56			
(46)	0·70	0·80	(52)	0·69				

Nos. (56) to (72) are soils from Europe.—Nos. (56) to (62) are from Russia and were sent by Prof. Nich, Menschutkin, Kaiser. University, St. Petersburg. No. (56) is a yellow sandy loam, "Souglinok," from Borovitsky, Novgorod. No. (57), dark gray loam, Prof. Docoutschaeff's type, "Solonetz" (barren black earth), Prilouky, Poltava. No. (58), brown gray loam, forest soil, Zenkovsky, Poltava. No. (59), dark gray loam, "Tschernosem," (black earth), Prilouki, Poltava. No. (60), sandy black earth, "Tschernosem," Zenkovetsky, Polkava. No. (61), black earth, "Tschernosem," Balashoff, Saratoff. No. (62), black earth, "Tschernosem," Zoubrilovka, Saratov. No. (63), white porcelain clay from Halle, Prussia. No. (64,) white porcelain clay from St. Yrieux near Limoges, France. No. (65), yellow gray loam from Florence, Italy, per Dr. C. L. Minor, of New York. Nos. (66) to (72) are from Great Britain and were collected for me by Prof. W. G. Brown, of Lexington, Va. No. (66) black garden soil, Kensington, London. No. (67), dark gray loam from coast near Brighton. No. (68), gray loam, Liverpool. No. (69), gray sandy loam, Donington, Lincolnshire. No. (70), gray sandy loam, Cambridge. No. (71), brown yellow clay, Inversnaid, Loch Lomond, Scotland. No. (72), brown clay, under Forth bridge, N. Queensferry.

The percentage of titanic oxide found in these respectively is as follows:

(56)	0·54	0·57	(62)	0·56	0·73	(68)	0·41	0·46
(57)	0·40	0·43	(63)	0·03	0·03	(69)	0·45	0·49
(58)	0·60	0·70	(64)	0·015	0·017	(70)	0·50	0·53
(59)	0·32	0·34	(65)	0·53	0·62	(71)	0·85	0·89
(60)	0·58	0·66	(66)	0·21	0·27	(72)	2·36	2·52
(61)	0·63	0·79	(67)	0·46	0·52	Average	0·54	0·62

This wide distribution of titanic oxide naturally suggests the examination of the rocks themselves. I have so far been able to examine only the following typical rocks, the localities of which have furnished also the samples for analyses already published: (73), Trachyte, Kühlsbrunnen. (74), Trachyte. (75), Trachyte, Drachenfels. (76), Hornblende andesite, Wolkenburg. These four were from the Siebengebirge. (77), Gabbro, Radauthal, Harzburg.* (78), Melaphyr, Ilmenau, Schneidemuller-berg. (79), Melaphyr, Plauenschen Grunde, near Dresden. (80), Nosean phonolite, Castle Olbrück, Laacher See. These afford the following:

	TiO_2 mentioned in published analysis.		TiO_2 found.
(73)	none	Zirkel, II, p. 181	0·22
(74)	none	" p. 182	0·86
(75)	0·38	" p. 181	0·64
(76)	none	" p. 212	1·14
(77)	none	" p. 116	0·10
(78)	0·89	" p. 55	1·01
(79)	trace	Zirkel I, p. 584	0·36
(80)	none	"	0·18
	Average		0·56

While the frequent association of titanium with iron (as indicated by the color after ignition), in these soils points to menaccanite as a source of the titanic oxide; yet the considerable amount of this substance in some of the clays and rocks containing little iron suggests that it may also result from titanite which has been observed† to be widely distributed in igneous rocks.

In conclusion I desire to thank those who have assisted me in this work by supplying the desired specimens.

Sept., 1891.

Art. LIV.—*Notes on a Missouri Barite;* by C. Luedeking and H. A. Wheeler.

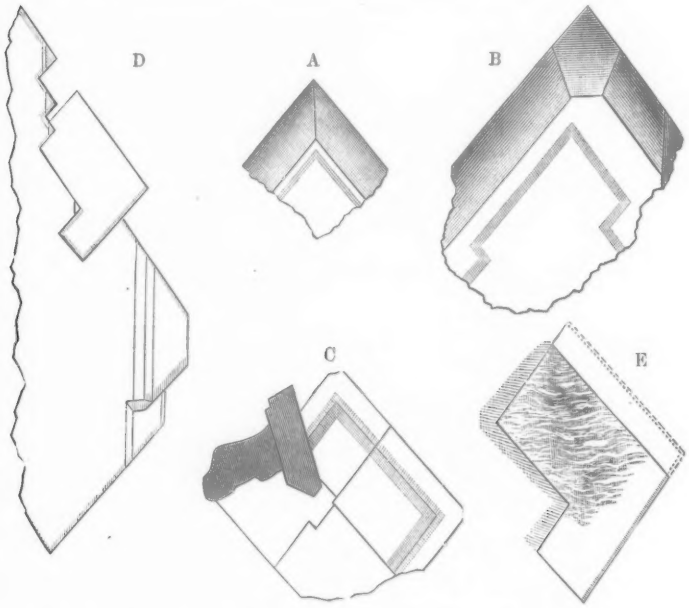
A variety of barite is found in Pettis County, Mo., that presents peculiar chemical and crystallographic characteristics. It occurs in clusters of simple and compound crystals that individually are quite perfect and which vary in size from 10 to 200^{mm} in length by 1 to 30^{mm} in thickness and are of tabular habit. The peculiarity of the crystals is the occurrence of

*I find in Bischoff III, page 467: Gabbro from Rodanthal bei Steinbruch, contains TiO_2—1·75 per cent.

† Dana's System of Mineralogy, p. 389.

white to yellowish thin bands in an otherwise normal colorless barite, and analysis shows that these bands consist of a mixture of the sulphates of barium and strontium with slight amounts of calcium and ammonium.

Two distinct types of the banded crystals occur, of which one type (A, B) is found near Smithton, while the other type (C, D, E) is found at Sedalia, both localities being within seven miles of each other in Pettis Co., Mo. They occur in clay associated with galena in the lead-bearing magnesia limestone series of Missouri, which latter in that locality usually has barite very abundantly associated with the lead ores.



The crystal, A, consists of the right rhombic prism, beveled by the right rhombic pyramid and truncated by the basal pinacoid; another crystal, B, is in addition modified by the macro- and brachydomes, which, like the pyramid, have very low values for the coefficient of the vertical axis. All the faces of the modifications of the A and B forms of crystals, except the basal pinacoid, are coated with an opaque white variety of barite, next to which is a colorless band followed by a narrow white band, the body of the crystal being clear and colorless. The inner white band is from 0·5 to 1·0^{mm} wide

and persistently occurs in all the Smithton specimens that have been examined in relatively the same position with respect to the development of the crystal, whether large or small in size. The white coating that fringes the crystals is usually superficial, as it most frequently is found to be underlaid by a clear wine-colored ground mass; in some crystals however the opaque matter entirely replaces this latter.

The simple tabular crystal C has a clear colorless interior inclosed within a subtransparent wine-colored band 1·5^{mm} in width, that is adjoined by a white opaque band 0·5^{mm} in width; both of these bands are parallel to the prismatic faces as likewise the cleavage crack shown in the drawing. The outer edge of this crystal is transparent but has the slight bluish tinge indicative of strontium.

The twinned group of crystals shown in D have the edges of the right rhombic prism modified by either one, two or three modifications of the macrodome, and truncated as usual by the basal pinacoid; in this type only the faces of the prism are coated with the opaque white barite, the rest of the material consisting of clear colorless and essentially pure barite. The thickness of this coating is variable on different faces of the prism, being appreciably greater on the upper face in some and on the lower face in other crystals and varying from 0·2 to 2·2^{mm} in thickness; but in every case the opaque barite is only found on the prismatic faces.

The crystal E is a member of the same cluster of crystals from which D was taken. It consists of only the simple rhombic prism which is thinly fringed with white barite, but on one of the basal faces is a series of irregular lines of a fine white pulverulent material that suggests the deposition of a sediment on an inclined surface. A subsequent deposition of clear barite has preserved this pulverulent matter *in situ*.

An analysis of the white barite showed it to be somewhat variable in composition, but the following gives its general character.

Barium sulphate	87·2 per cent.
Strontium sulphate	10·9 "
Calcium sulphate	0·2 "
Ammonium sulphate	0·2 "
Water	2·4 "
	100·9

The occurrence of ammonium sulphate in barite is quite novel. The amount seems to be somewhat greater in the yellow than in the white variety by about 0·1 per cent and is

always very small, and occasionally scarcely appreciable. The isomorphism of ammonium sulphate, mascagnite, with barite is worthy of notice.

When the powdered white or yellow material is heated in a closed tube an appreciable sublimate of ammonium salts is obtained and at the same time an empyreumatic odor is noticeable. It was thought that perhaps the sublimate might be due to the decomposition of nitrogenous organic matter by the heat employed. That this was not the case was proved by the fact that it was possible by cold extraction with water to obtain very decided Nessler reactions for ammonia. It is therefore assumed by the writers that the ammonium occurs as mascagnite in association with the other sulphates.

Specimens of these Pettis Co. barites were sent to Mr. F. W. Clarke, of the chemical department of the U. S. Geological Survey, and were kindly examined by Dr. W. F. Hillebrand, who confirms the presence of ammonia. Mr. J. S. Diller, of the U. S. Geological Survey, also examined them microscopically and finds that the opacity is probably due to the presence of myriads of cavities which seem to be filled with air.

We wish to herewith express our thanks to these gentlemen, as well as also to Dr. Hambach of St. Louis and Mr. Sampson of Sedalia for samples furnished.

ART. LV.—*The Contraction of Molten Rock;* by C. BARUS.

AT the request of Mr. Clarence King I made the following volume measurements on a sample of diabase which he furnished. In the method employed, both the contraction of the rock and of the vessel containing it, were measured simultaneously, and cooling was conducted so slowly that the viscosity of the latter remained indefinitely high relatively to the former, throughout. Four series of data are in hand, the last two of which are full and satisfactory. Thus if 3α be the mean coëfficient of actual volume expansion (or contraction), and 3β be the actual volume decrement on solidifying, where both 3α and 3β are referred to the unit of volume of solid rock at zero centigrade, I found in the third series between 0° and 1000°, $3\alpha = 250/10^7$; between 1100° and 1500°, $3\alpha = 470/10^7$; at 1095°, $3\beta = +39/10^3$; and in the fourth series, similarly, $3\alpha = 250/10^7$, $3\alpha = 468/10^7$, $3\beta = +34/10^3$, respectively. Fusion of igneous rock (diabase) is therefore not only quite normal in type, but sharp at a definite melting point. Thus the volume increments $(v_t - v_0)/v_0$, at consecutive temperatures, t, during

contraction of the originally liquid mass were found to be, for instance (fourth series): 0·0771 at 1421°, 0·0760 at 1388°, 0·0730 at 1319°, 0·0721 at 1305°, 0·0661 (sticky) at 1190°, 0·0652 (very sticky) at 1163°, ·0628 at 1112°, falling off eventually to 0·0285 at 1093°, 0·0223 at 914°, 0·0202 at 855°, etc. Conversely since sudden bulk contraction is a criterion for solidifying point, these results lead to sharp values for this datum.

Finally, the density of the original (cold) rock was 3·0178 (four measurements) and the density of the (cold) glass after fusion 2 717 (three measurements). Now I have been at considerable pains to show that the chemical equilibrium of a substance (solid or liquid) varies with pressure. Since, therefore, the glass obtained by fusion is permanently homogeneous in character, structural rock texture is due to pressure; i. e. pressure induces a redistribution of molecules, such that the smallest specific volume possible under the given conditions may result. Hence it is permissible to conceive a solution-fusion mechanism, in virtue of which, by the mere act of pressure, volume changes of an order of even 13 per cent may present themselves.

Art. LVI.—*Notes on Michigan Minerals*;* by A. C. Lane, H. F. Keller and F. F. Sharpless.

Contents: 1. Chloritoid [L. and K.] § 1. Historical introduction. 2. Summary of results. 3. Physical characters. 4. Chemical analysis. 5. Paragenesis. 6. Comparison with previous results.

2. Grünerite [L. and S.] § 1. Historical introduction. 2. Physical characters, 3. Chemical characters. 4. Comparison with other ferromagnesian monoclinic amphiboles.

3. Riebeckite [L.] § 1. Occurrence and optical character.

1. Chloritoid.

§ 1. This mineral has been known to occur in the Upper peninsula of Michigan for some years. It was first described, so far as we know, by Wadsworth† as occurring at Humboldt. It may be found about one thousand feet S. of the station of the D. S. S. and A. R. R., and occurs in scales 2^{mm} to 4^{mm} broad. It also occurs at points east and west in the same range, e. g. the Fitch Mine, S. 24, T. 47, R. 28, and from S. 29, T. 47, R. 26. Recently we have found it, in dark green

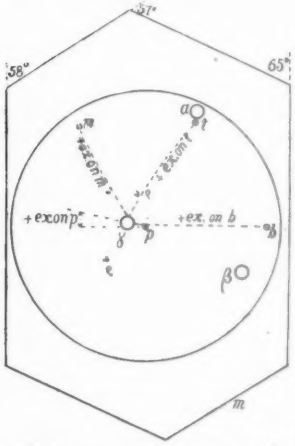
* From the laboratory of the Michigan Geological Survey, with the permission of M. E. Wadsworth, State Geologist.

† Bull. Mus. Comp. Zool., vol. vii, 1880, p. 45.

plates several centimeters broad and up to 4^{mm} thick at the Champion Iron Mine. As it was so very large, not very impure, and extremely like the masonite from Natick village, Warwick township, R. I., it seemed worth while to examine it both chemically and optically. The results have brought out some new facts, which we feel justified in giving now, since previous data have been neither complete nor accordant, even though we hope to continue our investigations into the chloritoid group.

§ 2. We may summarize our results as follows. All the Michigan chloritoids, as well as the masonite, a chloritoid from Pregratten, one from Leeds, Canada, and one from the Apennines, appear to be optically the same. They have the usual trichroism and are pronouncedly triclinic. The axis of mean elasticity (β) is inclined some 20° to the basis (001), so that of the twin lamellæ parallel to the basis, which commonly occur in three sets, that one has the greatest angle of extinction which is most blue in color. The horizontal dispersion is strong. Fig. 1 shows the lateral cleavages, and a stereographic projection on the basis of the orientation of the optical axes.

All the chloritoids that we have tested, i. e. those from Champion, Pregratten and Natick contain constitutional alkali. In this respect, as otherwise in qualitative composition they resemble hornblendes of like pleochroism. Ottrelite from Ottrez seems to be optically as well as chemically different, and less pleochroic.



§ 3. The detailed description of the Champion chloritoid is as follows: H. 6·5. Sp. G. 3·552. Cleavage basal, perfect, but often warped. One lateral cleavage (t) and traces of two or three others can be seen. The color is dark green, almost black to the naked eye. It is decidedly brittle.

The measurements given below, used in constructing fig. 1, were mainly made with the microscope. To a few of the better determined ones we append the probable error [P. E.]. The material is not suited for exact determinations.

The $\angle$ bpt = the $\angle$ between the traces on the basis of the two lateral cleavages nearest to the two directions of extinction.

$= 65°{\cdot}1$ [P.E. $= 0°{\cdot}088$]
$tpm = 57°{\cdot}3$
$tpb = 57°{\cdot}6$ [P.E. $= 0°{\cdot}374$]
$p : t$ (? the best cleavage) $= 80°\frac{1}{2} \pm 2°\frac{1}{2}$ (cleavage faces)
$: b$? $= 83\frac{1}{2}° \begin{matrix} +4° \\ -7° \end{matrix}$ " "
$: m$? $= 84° \begin{matrix} +10 \\ -10 \end{matrix}$ " "

These angles from the basis to the lateral cleavage were taken with a reflection goniometer. The lateral faces gave only a "schimmer."

The sense of the angle from p to t, m and b, is still uncertain, i. e. it is possible, though not probable, that one or more of them may be on the other side of p. The angle from the negative extinction to the trace of b, in basal sections, is 14° [P.E. $= 0°{\cdot}42$]. The angle from the positive extinction to the trace of t should be, by calculation 11°. Certain observations give 12°·3. The directions of extinction in basal cleavage fragments vary from being nearly parallel to the trace of t, to being nearly perpendicular to the trace of b, which last position agrees best with the observations of previous writers. This variation is doubtless due to superposed twinned lamellæ. The thinner fragments which have least signs of twinning, i. e. sharpest extinctions and purest pleochroism, give an extinction angle about as drawn.

For t, i. e. in cleavage bits that have a strong pleochroism, blue to yellow, and appear to be parallel to t, the extinction angle against the trace of p averages 18°·6, but there is a strong dispersion of the extinction; ex. $\rho <$ ex. v. Values as high as 21° occur often. Such cleavage fragments are very frequent.

In cleavage bits that are apparently parallel to b, and have a pleochroism from green to yellow, the extinction angle is almost inappreciable. A section artificially cut nearly perpendicular to p and parallel to m (probably) gave an extinction angle of 8°. The best cleavage follows t, the next b, a very poor one m, and there seem to be traces of a cleavage perpendicular to b.

The refraction by the de Chaulnes method is about 1·75, the bi-refraction, judging from the brightest polarization colors, about 0·007, not above that of quartz. [According to Lacroix it is 0·015, but doubtless it varies with the ratio of Mg : Fe.]

In convergent light the positive acute bisectrix emerges doubly obliquely, i. e. so that when the cross is formed, neither arm passes exactly through the center of the field of view.

The arm corresponding to the plane $\gamma\beta$ lies nearest the center. The *real* obliquity of γ appears to be about 17°. The direction of γ from the center of the field of view, i. e. the normal to p, makes an angle of about 150° with the direction of β; i. e. $\gamma\ p\ \beta = 150°$ circa. The optical angle does not appear large. [According to Lacroix it is 45°.]

From the double obliquity of the axial image it follows that the position of formation of a cross by closing in of the hyperbolas, which occurs approximately when β is in the direction of one of the principal planes of the nicols, will *not* be a position of extinction. The angle to be turned varies but is always noticeable. The formation of the cross is almost exactly parallel to the trace of t, and makes an angle against the direction of extinction of from 8° to 11°. The axial image is of course liable to disturbance from the twinning.

The direction of γ from the normal to p also seems to make an angle of about 80° with the trace of b, (in the sense opposite to that of the angle bt?).

These data harmonize fairly, but not absolutely, and it must be remembered that the directions of extinction do not pass exactly through γ. By *every* indication, however, γ lies within the small circle marking its position.

The pleochroism is as usual:—γ, yellow; β, blue, (not so far as I have noticed reddish); α, green. This so far as color is concerned is precisely that of certain hornblende, approaching glaucophane, which occurs in the crystalline schists and has a cellular structure [e. g. specimen No. 11270 of the Mich. Geol. Survey.] The pleochroism of such hornblende has also been noted by Lacroix. Moreover, such hornblendes like chloritoid contain alkali as well as Fe, Mg, Al_2, Fe_2 and Si.

Transverse sections of the plates of chloritoid frequently show twinned lamellæ parallel to the basis, though this Champion chloritoid has sometimes thick untwinned plates. In such cases, as might be expected if the twinning was according to Tschermak's law for the micas, there are three sets of lamellæ, with different extinction angles. The larger extinction angles are in those lamellæ where the pleochroism is most purely blue in one direction,—that near to β. The other lamellæ where the change of color is from green to yellow have far smaller extinction angles. When one set of lamellæ have a very large extinction angle, the other two sets have generally quite small angles.

§ 4. The analysis of the carefully selected material gave the following results:—

		Mol. ratio.	
SiO_2	24·29	·4048	
TiO_2	0·28	·0035	
Al_2O_3	34·00	·3333	·3992
Fe_2O_3	10·55	·0659	
FeO	20·51	·2850	
MnO	trace	——	·3432
MgO	1·29	·0430	
CaO	0·61	·0152	
K_2O	0·97	·0103	
Na_2O	0·35	·0059	·3906
H_2O	6·75	·3744	
	Sum 99·60		

From these figures we deduce the formula $H_{16}Fe_2Al_{16}Si_8O_{55}$ or $8H_2O{\cdot}7FeO{\cdot}8Al_2O_3{\cdot}8SiO_2$, which is nearly identical with that now generally accepted for sismondine.* It will be observed, however, that the composition of our mineral, as we have determined it, differs from the published analyses of the latter in two respects: the iron is largely in the ferric condition, and alkalies occur in notable quantity. Since the microscopic examination of the material revealed only traces of sericite, and the magnetite had been carefully extracted with the magnet, it is evident that the ferric oxide as well as the alkalies are essential constituents of this chloritoid. The ferric oxide without doubt replaces part of the alumina, while the alkalies, it may be assumed, are substitutes for some of the hydroxyl-water. We have reason to believe that alkalies have been overlooked in many of the former analyses of chloritoid and the allied species. An examination of the masonite from Natick, for instance, showed them to be present to upwards of two per cent—the soda predominating—and a qualitative test disclosed small amounts of both potash and soda in the Pregratten occurrence. The titanic acid in our analysis was doubtless contributed by a slight admixture of ilmenite or rutile.

§ 5. Now, comparing our data with those generally given, we find that all authorities agree,—first, in the pleochroism; secondly, that γ is the positive acute bisectrix; thirdly, that there is a marked dispersion, $\rho<\nu$. Lacroix also mentions the horizontal dispersion. There is a decided difference, however, as to the direction of the axes of elasticity, γ, β and α. It is perhaps worth noting that in Rosenbusch's "Microscopic Physiography" there is a statement on page 494, that in masonite the pleochroism of α is blue and β green. This is

* Groth, Tabell. Uebersicht, 3 ed., p. 118.

not true and we are told to strike it out in the errata, but the statement may have arisen from the fact that β is at a much greater angle to the basal cleavage than a, as we believe that Sanger was still at work on the chloritoids when he was interrupted by his last illness, and never put his work in final shape. For, as we have seen in our material, sections which show a change from blue to yellow are those which have the greatest extinction, whereas according to the orientation given in the Physiography they should have no angle of extinction. The ottrelite from Ottrez, however, shows no marked difference of color in the different twin lamellæ parallel to the basis. Lacroix merely remarks that the extinctions are longitudinal but much dispersed.

The triclinic character of chloritoid seems assured, for: (1), sections showing the pleochroism of β and γ, i. e. perpendicular to a, have a large and dispersed angle of extinction. Consequently if monoclinic, a must be parallel to the orthodiagonal $\overline{b}$, inasmuch as β and γ are inclined to the basal cleavage. Then lateral cleavage fragments showing the pleochroism from blue to yellow should also exhibit the directly perpendicular emergence of a negative bisectrix. This is not the case.

(2.) The lateral cleavages have not a corresponding symmetry.

(3.) In a monoclinic mineral the emergence of an axial image from a fragment due to a solitary perfect cleavage cannot be doubly oblique, but when the axial image is in the shape of a cross, one arm must pass through the center of the field of view. Or, which amounts to the same thing, when the mineral is in the position of extinction with parallel light, on changing to convergent light, without disturbing the mineral, the axial image must be that of a cross with one bar extending directly across the field of view. In this case, although the possible effect of twinning makes observations on basal sections the least trustworthy, it is nevertheless pretty certain that the above condition is not fulfilled.

The various apparent lateral cleavage lines are numerous. Lacroix gives a third cleavage bisecting the acute angle between the two better ones, while Rosenbusch describes it as bisecting the obtuse angle. Traces of both seem to occur, or rather it seems as if lines corresponding both to "druckfigur" and "schlagfigur" occurred. Obviously however in crystals made up of twin lamellæ as these so often are, cleavage lines are liable to pass, or be imposed, from one lamella to the next at an angle of about 60° from their proper direction.

§ 6. The discussion of the paragenesis and occurrence must be left till later. Suffice it to say that the Champion chloritoid occurs in a schist which bears a general resemblance to the

schist famous for its large pseudomorphs of chlorite after garnet. The most abundant impurities are ilmenite and magnetite. Rutile, quartz and sericite are much less common. The analyzed material was examined under the microscope and, though not absolutely pure, was but slightly contaminated. The chloritoid is evidently averse to enclosing the brown mica and chlorite which also occur in the rock and they occur only at its very margins. All the Michigan chloritoids, so far as yet known, occur in altered arkoses or similar rocks, in one case both in the cement and in the basic and acid pebbles of a conglomerate.

2. Grünerite [L. and S.]

§ 1. There is a peculiar amphibole, associated with certain iron ores of Lake Superior, which has been called both actinolite and anthophyllite. The latter name is due to Brush* who rightly recognized that it was essentially a silicate of Fe and Mg. He was followed by Brooks and Julien.† On the other hand Wichman‡ and Wadsworth§ rightly recognized that it was not orthorhombic, and referred it to actinolite. They were followed by Van Hise,‖ while C. F. Wright in some of his work called the rock in which the amphibole occurs an anthophyllo-actinolite schist.

§ 2. It is in reality a ferro magnesian monoclinic amphibole, corresponding closely to the description of grünerite given by Lacroix¶. The strong refraction, like that of epidote, is noticeable, not only in the thin section but in the hand specimen, which has in consequence a peculiarly high silky luster. It is much greater than that of common blue green hornblende or actinolite, but less than that of garnet, and by de Chaulnes' method is 1·7. The bi-refraction is also strong. It varies in specimens from different localities, but is always stronger than that of actinolite and does not differ markedly from that of the talc into which the mineral readily changes, so that $\gamma - \alpha$ is always $>0{\cdot}030$.

The polysynthetic twinning parallel to (100) is commonly well marked, and with the strong optical powers distinguishes it at a glance from actinolite. A striation parallel to $(10\bar{1})$, which should be more properly (001)**, is in one case developed. The mineral is colorless or slightly greenish or brownish, but

* Rep. Mich. Geol. Survey, I, p. 114. † Idem, II, p. 24.
‡ Report Wis. Geol. Survey, III, p. 604.
§ Notes on the Geol. of the Iron and Copper Districts of Lake Superior, p. 47, *et passim*.
‖ This Journal, xli, 1891, pp. 119 and 131.
¶ Lévy et Lacroix, "Minéraux des Roches," 1889.
** G. H. Williams, this Journal, xxxix, 1890, p. 352.

never more than faintly pleochroic. The angle from $c:\chi$ is between 15° and 20°. We endeavored to get the curve of the extinction angles in the prismatic zone, by revolving a fiber in Nachet's "cuve goniometrique" filled with mono-brom-naphthalin. Owing to the twinning the results were not satisfactory but in a general way the curve starting from a 0° extinction at 010 rose with an initial slope of about 0·7 until perpendicular to the cleavage faces the extinction was nearly 20°. After that it varied but little.

From these observations* and from the relative retardations of pinacoidal sections as manifested in their polarization, values of -2 V between 50° and 80° are deduced. The specific gravity of a specimen contaminated with quartz alone was found to be 3·2 to 3·3.

§ 3. The purest material at hand in sufficient bulk for analysis seemed to be some from the Champion Mine, after removing all the iron oxides from it. Unfortunately the crushing of a larger amount for analysis introduced unexpected impurities. The mineral is changed to talc in spots, and there was some entangled quartz though apparently not enough to account for the high percentage of SiO_2.

The following analysis which was made on material first treated with the magnet to remove magnetite, and then briefly with HCl to remove martite and hematite, has therefore merely a qualitative value, but shows very clearly by the absence of lime that the mineral is not actinolite.

SiO_2	76·32
Al_2O_3	0·56
Fe_2O_3	0·99
FeO	6·96
MgO	12·47
CaO	----
$(Na,K)_2O$	*tr.*
H_2O	2·80
Sum	100·20

The alteration to talcose matter is strictly pseudomorphic and follows lines of alteration parallel to the polysynthetic twinning (100). It must be quite extensive. The mineral is in small fibers, associated with quartz and iron ores, commonly

* It may be shown, starting from Lévy's equation 3, p. 20, that $\cos^2 V (\sin \chi + 1) = \cos^2 \theta (\sin \chi - 1) - 1$, when V is half the optical angle, $\theta = \angle \dot{c} : a$, and χ the angle from the plane (010) to the prismatic plane in which the angle of extinction first becomes equal to θ. We may also show that $\cos^2 V (\tan \theta + \cot \theta) = \tan \theta +$ (initial steepness of curve of extinctions, i. e., $\frac{dy_0}{dx_0}$)

magnetite. Garnet, common blue green hornblende and brown mica are associated with it at times, marking stages of transition to ordinary hornblende schist.

§ 4. Judging from some slight variation in the optical properties of different occurrences, it seems likely that they are not chemically identical. We really need one general name for all monoclinic ferromagnesian amphiboles, without regard to varieties differing merely in the ratio of Mg : Fe. To amphiboles of this kind the names antholite, kupfferite, silfbergite, cummingtonite and grünerite have been applied. The first name, antholite, has been used also for anthophyllite and is confined by Dana to the very magnesian varieties. Typical kupfferite seems to be chromiferous, but otherwise practically the same as antholite, though its physical relations to the amphiboles have not been determined so far as we know. Silfbergite* has 8·39 per cent MnO, as well as 30·49 per cent FeO, and 8·74 per cent MgO. The name cummingtonite was given by Dewey† to a mineral from Cummington, Mass., which he supposed to be a kind of epidote. There are two minerals from Cummington which have been taken for it, as the original description is not very explicit. The one is a ferromagnesian monoclinic amphibole in truth, with only a mere trace of MnO, as we have personally found. This we also find to be very much like our mineral but larger and coarser. It agrees in luster, color, brittleness and specific weight, 3·2. The mineral associations, optical properties and frequent twinning are also similar. It has been analyzed by Smith and Brush.‡

The other mineral is a manganese mineral akin to rhodonite. It has been analyzed by Muir§ and the name is used in this latter sense by Rammelsberg, Groth and other writers up to the present day.

With grünerite‖ there is physically the closest agreement. Grünerite however is supposed to contain only about 1 per cent MgO, and to be somewhat heavier, perhaps also more birefractive.

What the average ratio of Mg : Fe in the Michigan amphiboles under consideration is,—they are of widespread occurrence, and what their relations to kupfferite, etc., are questions that require work upon a large range of authentic material to settle. It seems indeed possible, in view of the tendency to repeated twinning parallel to 100, that anthophyllite may be

* This Journal, xxvi, p. 157.
† This Journal, viii, 1824, p 59.
‡ This Journal, xvi, 1853, p. 48.
§ Thomson's Mineralogie, vol. i, p. 493.
‖ The diaeresis which strictly should be over the *u* is dropped by Rammelsberg, Tschermak, Naumann, Zirkel, Groth and Chester, and sometimes by Lévy and Lacroix and Max Bauer, while Dana, Lapparent, Descloizeaux and Ramsay retain it.

due to such molecular or submicroscopic twinning, for such a structure would produce a rhombic symmetry. Then anthophyllite and grünerite would be related, as orthoclase (submicroscopic microcline) and albite, or the two kinds of natrolite.

Considering the unfortunate ambiguity of the word cummingtonite, its hitherto more imperfect optical description, and the greater length of the word, it seems preferable to denote the allied Michigan amphiboles as grünerite, pending further investigation. Inasmuch as they are concomitants of the iron ores, it seems the more proper to lay stress on the $Fe_4Si_4O_{12}$ molecules.

3. Riebeckite or Crocidolite. [L.]

Our knowledge of this group of amphiboles is rapidly increasing, but it has not yet been so frequently observed that a new occurrence is devoid of interest. I have observed it as a secondary fibrous growth on the primary hornblende of a syenite.* It occurs much as those fibers do, that we often see in more basic rocks growing out from patches of uralite into the adjacent feldspar, and it is worth noting that uralite patches are often most bluish at the margin. The growths I have noticed answer precisely to those described by Cross,† and verify his observations, as I can testify from a personal examination of his sections, which he kindly afforded me. The vertical axis and orientation are parallel to those of the original hornblende, but the angle of the + extinction is very large, somewhere about 75°, above, to the front, so that as Cross notes the nearest extinction is on the other side of the vertical axis from that of common hornblende. The pleochroism is,—α blue to greenish blue; β violet or reddish blue; γ yellow. The bi-refraction is weak. The fibers are often separated from the dark green hornblende by a sharp crystallographic line. At other times they seem to mingle and compensate, forming an isotropic band.

Michigan Mining School, Houghton. May 23d, 1891.

* No. 583 of the Mich. State Coll.; 325 paces N., 975 paces W., of the S.E. corner of Sec. 17, T. 49, R. 25.

† This Journal, xxxix, 1890, p. 359.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Two new Modifications of Sulphur.*—Engel has observed that if one volume of solution of sodium thiosulphate, saturated at the ordinary temperature, be poured with continual agitation into two volumes of a solution of hydrochloric acid, saturated at 25°-30° and cooled to about 10°, sodium chloride is precipitated, and the resulting thiosulphuric acid is so stable that the liquid can be filtered. At first the filtrate is colorless, but it soon becomes yellow, the intensity of the color increasing gradually, and sulphurous oxide being evolved. If now, after the liquid has become deep yellow in color, but is still entirely transparent, it be agitated with its own volume of chloroform, the chloroform removes the yellow color; and on being allowed to evaporate, deposits orange-yellow crystals of sulphur, quite different from the octahedral variety. Friedel describes them as rhombohedral showing the cross and rings of uniaxial crystals in polarized light. The rhombohedron is very obtuse, *pp* (normal) $= 40° 50'$. These crystals have a density of 2·135, greater than that of octahedral sulphur. At first they are transparent but in three or four hours they pass into an amorphous insoluble form. They fuse below 100°, passing into the pasty condition and becoming partially soluble in carbon disulphide. If, however, the solution of thiosulphuric acid in hydrochloric acid be allowed to stand, the sulphur separates as a yellow flocculent precipitate, completely soluble in water. The solution is yellow, but decomposes rapidly, yielding the ordinary pasty sulphur of the thiosulphates. The original precipitate also agglomerates and passes into the same insoluble form, without evolution of hydrogen sulphide. These varieties of sulphur are probably polymerized atomic forms.—*C. R.*, cxii, 866; *J. Chem. Soc.*, lx, 976, Sept. 1891. G. F. B.

2. *Chemistry of the Carbon compounds or Organic Chemistry;* by Victor von Richter, University of Breslau. Authorized translation by Edgar F. Smith, University of Pennsylvania. Second American from the Sixth German edition. 12mo, pp. 1040. Philadelphia, 1891. (P. Blakiston, Son & Co.).

The new edition of this excellent text-book will be very acceptable to students of Organic Chemistry. The introduction contains much new and valuable matter upon the later physical and chemical methods of fixing the mass as well as the structure of the molecule, the sections on stereochemical theories and the tautomeric theory being noteworthy. In the special part, Class I is devoted to the Fatty bodies or the Methane derivatives and Class II to the Benzene derivatives. The new edition shows a large introduction of new matter, the chapter on the carbohydrates having been re-written, the sections relating to the tri-, tetra- and penta-methylene series greatly enlarged, and the whole

brought up to date. Dr. Smith's translation is clear, accurate and in every way admirable. The volume as it now stands seems to us one of the best and most complete text-books in the English language. We regret sincerely the recent death of its distinguished author, who has done so much in his text-books to present the science of chemistry in a compact and yet comprehensive form. G. F. B.

3. *A System of Inorganic Chemistry;* by WILLIAM RAMSAY, Ph.D., F.R.S., Professor of Chemistry in University College, London. 8vo, pp. xvi, 700. Philadelphia, 1891. (P. Blakiston, Son & Co.).—The system of classification adopted in this book is somewhat remarkable. "After a short historical preface the elements are considered in their order; next their compounds with the halogens, including the double halides; the oxides, sulphides, selenides and tellurides follow next, double oxides, such as sulphates, for example, being considered among the compounds of the simple oxides with the oxides of other elements; a few chapters are then occupied with the borides, carbides and silicides and the nitrides, phosphides, arsenides and antimonides; and in these the organo-metallic compounds, the double compounds of ammonia, and the cyanides are considered; while a short account is given of alloys and amalgams." Special chapters are appended treating of spectrum analysis and of the periodic law; the former chapter considering also the chemistry of the rare earths. Since the author tells us that "no systematic text-book has been written in English with the periodic arrangement of the elements as a basis," his attempt to supply this deficiency in the present volume has resulted in the above classification. He criticises as ancient and arbitrary the electrochemical line of demarcation between metals and non-metals, and says that too great importance has hitherto been assigned to the distinction between acid hydroxides and basic hydroxides. Moreover, the chemistry of text-books he thinks has almost always been influenced by commercial considerations. While the absolute classification according to the periodic law here adopted brings out prominently the quantitative affiliations of the elements, yet their qualitative relations are well nigh lost sight of. Moreover, the above mentioned arrangement of chemical compounds would seem likely to be confusing to the student. Of course the author's reputation is a guarantee of the accuracy and clearness of statement of the book. Moreover, its mechanical execution is excellent, and its size convenient. G. F. B.

4. *An Introduction to the Mathematical Theory of Electricity and Magnetism;* by W. T. H. EMTAGE, M.A., Examiner in the School of Natural Science, Oxford. 12mo, pp. viii, 228. Oxford, 1891 (Clarendon Press). This little book supplies a want which has long been felt for a text book treating the mathematical theory of electricity within a compass suited to the brief course generally available. It is clearly written, accurate and follows the best methods. G. F. B.

5. *Chapters on Electricity:* An introductory text-book for students in College; by SAMUEL SHELDON. pp. 351–452. New York, 1891. (Charles Collins and the Baker & Taylor Co.).—These chapters on Electricity are reprinted from the new (fourth) revised edition of Olmsted's Natural Philosophy. They give a concise and systematic statement of the most essential principles and phenomena in the subjects of Electricity and Magnetism as now understood. The treatment is of necessity very brief but if supplemented by the illustrations and explanations of the class-room, the book should give the average student a satisfactory elementary knowledge of his subject.

6. *Apparent change in electrochemical equivalent of copper.*—Certain observers have maintained that the electrochemical equivalent of copper changes with the density of the current per square millimeter of the surface of the electrodes. J. VANNI shows that the conditions of acidity of the bath produce the discordant results obtained by previous observers. When sulphuric acid is present in excess, the electrodes are attacked. By making a normal solution with a definite proportion of free sulphuric acid, concordant results can be obtained with a copper voltameter. The author gives results of his experiments and shows that the deposition of copper can be employed with great exactness to measure electrical currents if the proper care is taken in forming a normal solution without too much acidity.—*Ann. der Physik und Chemie*, No. 10, 1891, p. 214, 221. J. T.

7. *Electrolytic generation of Gas in a closed space.*—M. CHABRY of the Société de Biologie has succeeded in obtaining by this means a pressure of 1200 atmospheres. The electrolyzed liquid was a 25 per cent soda solution. The current had a strength of 1½ amperes and was very constant during the experiment.—*Nature*, Oct. 15, 1891. J. T.

8. *Upon the damping of electrical oscillations.*—An important paper on this subject has been written by V. BJERKNES. The author discusses the mathematical theory and shows that the multiple resonance discovered by Sarasin and de la Rive can be explained by the phenomena of damping. Their results are therefore in accord with the experiments of Hertz. The author expresses his obligations to the work of Poincaré (Électricité et Optique, II, Paris, 1891).—*Ann. der Physik und Chemie*, No. 9, 1891, pp. 74–101. J. T.

9. *Velocity of Electrical waves in solid insulators.*—AVONS and RUBENS in a previous article (Wied. Ann., vol. xlii, p. 582, 1891), described a method of measuring electrical waves in dielectrics, which was an extension of Hertz's method. Its peculiarity consisted in the employment of a bolometer instead of an electric spark for the observation of maxima and minima of oscillations. They have extended their work to an investigation of Maxwell's law connecting the dielectric constant with the index of refraction of the dielectric, and find a very satisfactory agreement between his theory and their experiments. Maxwell's

law is $n^2=\mu$ where n = index of refraction and μ = dielectric constant.

The results of the authors are embodied in the following table (λ is wave length).

Dielectric.	μ	$\sqrt{\mu}$	$\lambda = 6m$ n	$\lambda = 6{\cdot}10^{-7}m$ n
Fluid paraffine	1·98	1·41	1·47)	1·48
Cooling paraffine	2·08	1·44	1·48)	bis
Solid paraffine	1·95	1·40	1·43	1·53
Glass I	5·37	2·32	2·33	1·51
Glass II	5·90	2·43	2·49	1·53
Castor oil	4·67	2·16	2·05	1 48
Olive oil	3 07	1·75	1·77	1·47
Xylol	2·35	1·53	1·50	1·49
Petroleum	2·07	1·44	1·40	1·45

—*Ann. der Physik und Chemie*, No. 10, 1891, pp. 206–213.

J. T.

II. Geology.

1. *On the British Earthquakes of 1889;* by C. Davison, of King Edward's High School, Birmingham, (Geol. Mag., viii, 1891.) —The more important conclusions of Prof. Davison's paper are presented in the following citations from pages 10, 20 and 28.

I believe we may, with some probability, conclude: (1) that the Edinburgh earthquake was caused by a slip of the fault marked BB on the map, at a spot vertically below the position indicated for the epicentrum, and therefore not far from the middle of the fault, where, probably, the throw is a maximum and where earthquake-action has been most frequent or most intense; (2) that, on account of the simple character and short duration of the disturbance, the horizontal length of the fault over which the slip took place was very short, possibly less than a mile; (3) that the slip of the downthrow side was downward or that of the upthrow side upward, resulting, in either case, in an increase of the throw of the fault in the neighborhood of the seismic focus; and (4) that, while the region of maximum slip, the focus of the earthquake proper, was probably at a depth of several (perhaps about 8) miles, the slip extended upwards to within a short distance of the surface, this part of the slip-area being the focus of the sound-vibrations.—p. 10.

In both the Edinburgh and Lancashire earthquakes, the shock and sound, we have reason to believe, were caused by slipping along well-known faults, the foci of the sounds being nearer the surface than the foci of the corresponding shocks. In both, also, the area over which the slip took place must have been very limited in extent: and, while the amount of the slip may have been greatest near the center of the Lancashire area, it must certainly have died away toward its upper and lateral margins.

Now, the seismographic records recently obtained by Prof. Milne and others in Japan show that earthquakes usually begin with a series of tremors very small in amplitude and very rapid in period, from six to eight occurring every second, but becoming slower before the shock takes place. These may last for many seconds or even several minutes. Following, and continuous with them, come the sensible vibrations, of larger amplitude and longer period, about three to five occurring in every second. One or more of these, attaining a still greater amplitude and longer period, of one or two seconds each, constitute what are generally known as the principal shock or shocks. The earthquake closes with vibrations of smaller amplitude, but which have a period so long that no record of them can be obtained. The earliest tremors, on the other hand, are not registered on account of the smallness of their amplitude, and, in all probability, as Prof. Milne suggests, the "minute movements which have been recorded are the continuation of still smaller and more rapid movements which . . . . have never yet been rendered visible." It is to these supposed rapid vibrations which form the front portion of an advancing earthquake, that Prof. Milne attributes the origin of the earthquake-sounds. We may conclude from these observations that, initially at any rate, the period of the vibrations increases and decreases with the amplitude.

Now, from different parts of the area over which a fault-slip takes place, there must proceed vibrations differing greatly in amplitude, and therefore also in period. From the central portions of the slip-area will come, as a rule, the vibrations of largest amplitude and longest period; while, from the margins there will proceed minute vibrations of a period so short that they may be perceptible only as sound. The position of the line separating the marginal and central parts of the slip-area will depend only on the amplitude of the vibrations corresponding to the period of the lowest sound that can be heard; it will not at all depend on the amount of the slip at the center of the area, *i. e.* it will be independent of the *intensity* of the shock.—p. 10. This theory explains (1) the fact that the sound-area is not concentric with the disturbed area, and the sound-focus is nearer the surface than the rest of the seismic focus; (2) the fact that, in great earthquakes, the sounds are heard only within a comparatively small area immediately surrounding the epicentrum.—pp. 20, 21.

With one possible exception (that of Ben Nevis), the earthquakes of 1889 are typical examples of British shocks—they occurred in districts where earthquakes are rarely felt, and their disturbed areas are circular or only slightly elliptical in form. Turning to a more distinctly seismic area, Switzerland for example, we find that the disturbed areas are often extremely elongated, the longer axes being parallel to those of the neighboring Alpine chain; earthquakes are more frequent, their intensity, as a rule, is greater, and much larger areas are disturbed. Different stages in the geological history of a district are

characterized by different kinds of earthquakes. The Alpine system is not yet old, fault-formation is still in progress, and the fault-slips are long and frequently recurring. In Great Britain, we meet with a later stage. Fault-formation in our seismic area is more advanced, and slipping takes place so slowly and over distances so short, that our earthquakes are rare and the areas disturbed by them more or less circular in form.

Every stage in the process, however, requires investigation, and that of which our British earthquakes are witness is certainly deserving of attentive study. Unattractive though it may be at first sight, the epoch immediately preceding the death of a mountain-chain, is at least as interesting to the geologist as the more vigorous periods of origin and growth.—pp. 28, 29.

2. *On the Formation of Graphite in Contact-metamorphism.*—Graphite is found naturally in various Archean rocks. Generally it occurs in beds or pockets, in gneiss, mica slate, clay slate, granular limestone, etc.; whence is obtained most of that used in the arts. Besides this, a second mode of occurrence of graphite, which is of great interest, is that in which in certain Archean rocks it replaces either wholly or partially, the mica. Graphite-mica-schists are known, and also graphite-gneisses, in which the scales of mica in ordinary mica-schists and gneisses are partly or wholly replaced by scales of graphite; and a schistose rock called graphite-schist exists which consists substantially of graphite and quartz. Even more noteworthy is the occurrence of graphite scales in granite, in place of the usual mica scales. Beck and Luzi have now observed the occurrence of beautifully crystallized graphite in strata which have been metamorphosed by contact with eruptive rocks, and have proved that these graphite crystals have originated in the amorphous coaly substance existing originally in the clay slates and quartzose schists. In the Pirna and Kreischa sections in Saxony, there are upper Silurian clay slates and quartz schists which are very rich in carbon particles; these slates and schists lying partly within the region of contact with granite and syenite. Now it is within this contact-region as the authors have shown, that these strata have been converted into rocks rich in graphite. For the examination, they used a very rich chiastolite slate and a graphite-quartzite. The former occurs in layers in the highly metamorphosed upper Silurian grauwacke of Burkhardtswalde. The latter is a genuine contact rock in the immediate vicinity of the granite and occurs in the Röhrsdorf valley near Kreischa. Both these rocks have come from the original quartz-schist, their structure and composition alike showing them to be true contact-products. In the chiastolite slate, the graphite has taken the place of the finely divided coaly substance easily combustible in the Bunsen flame previously existing in the quartz-schist. Isolated from the rock, it appeared as completely opaque irregular masses dark gray in color and having a metallic luster, and from 0·003 to 0·02 mm. in diameter; the carbon particles in the un-

altered schists not being over 0·001 mm. in diameter. Moreover, well defined single graphite crystals were observed having a hexagonal contour. The Röhrsdorf quartzite is still richer in graphite, and it is more beautifully crystallized. The rock itself is seen under a magnifier to consist essentially of a mixture of quartz and graphite, the latter feeling greasy to the touch and giving a metallic streak. Some of the crystals were 0·3 mm. in diameter. On chemical analysis, the chiastolite graphite gave 98·84 per cent carbon and 0·21 per cent. hydrogen; the quartzite-graphite 99·94 per cent carbon and 0·05 per cent hydrogen. In amount the quartzite contains about 2 per cent of the graphite, its density being from 2·62 to 2·637.—*Ber. Berl. Chem. Ges.*, xxiv, 1884, June, 1891. G. F. B.

3. *Geological Survey of Alabama*, E. A. Smith, State Geologist. *Report on the Coal Measures of the Plateau region of Alabama*, by Henry McCalley, including a report *on the Coal Measures of Blount County*, by A. M. Gibson. 238 pp. 8vo, with a map of the Coal-fields and two geological sections across the Plateau region.—The Coal-measures of all the Plateau region, about 4500 square miles in area, are here described except those of the Warrior Coal-field which were reported upon in 1886. The region is one of broad gentle undulations in the bedding, and is divided by wall-sided valleys which are cut down to the Subcarboniferous and inferior strata. The coal beds belong for the larger part to the lower part of the coal-measures and the most productive bed, the Main Etna, 2 to 5 feet thick, is below the Lower Conglomerate or Millstone Grit. Under this there are four other beds separated by 20 to 100 feet of shale. The Subcarboniferous beds, below the coal-measures, consist of a limestone, the probable equivalent of the Chester group, resting on shales and sandstone, in all perhaps 1000 feet in thickness, and underneath these, about 400 feet of cherty or siliceous limestones. All there is of Devonian in Alabama is a stratum of Black shale not over 10 or 15 feet thick.

4. *Geological Survey of Missouri*, *Bulletin No. 5*, Arthur Winslow, State Geologist. 86 pp., 8vo.—This Report contains a paper by Erasmus Haworth, on the age and origin of the crystalline rocks of Missouri, and another by G. E. Ladd, on the clays and building stones of certain western central counties tributary to Kansas City. Mr. Haworth concludes that the rocks of the iron region, granite and "phorphyry," are of igneous origin, and this makes the iron ore deposits also igneous. As stated in the Preface to the Report, Pumpelly, in his survey of the region, decided that the rocks and ore were metamorphic.

5. *Geological Survey of Georgia.* First Report of Progress, 1890–91, by L. W. Spencer, State Geologist. 128 pp. 8vo.—This report, after observations on the topography of the State, treats of the Cretaceous and Tertiary formations, presents briefer notes on the older strata, and gives some account of phosphate beds and other mineral materials of economic value.

6. *Geological facts on Grand River, Labrador;* by AUSTIN CARY. The following note is to be added to the sentence on p. 421 (line 14 from top) in the November number.

"Our measurements proving worthless on account of the difficulties under which they were taken, the smallest estimate made by the party on the spot was given. A measurement since made by Mr. Henry G. Bryant, of Philadelphia, makes the height of the fall 316 feet, from which the height of the basin wall will not much vary."

The adjective "gneissic" in line 14 of p. 420 should be erased, as the nature of the rock was not positively determined.

7. *Index to the known Fossil Insects of the World, including Myriapods and Arachnids;* by S. H. SCUDDER. Bull. U. S. Geol. Surv., No. 71. 744 pp. Washington, 1891.—Contains exact references, arranged chronologically under each species, to all the scientific publications where fossil insects are described and figured, with the locality and horizon of each. The catalogue is divided into the sections, Paleozoic, Mesozoic, and Cenozoic, and the classes and species appear alphabetically under the various orders. An index of generic names completes the work.

8. *Stones for Building and Decoration;* by GEORGE P. MERRILL. 453 pp., 8vo. New York, 1891. (John Wiley & Sons).—There are few subjects of more general interest and about which it is at the same time more difficult to obtain precise scientific information than that of Building Stones. Mr. Merrill's excellent volume, therefore, fills an important gap and should be highly valued by a wide range of readers. The book is divided into four parts of which the first gives a concise account of the minerals entering into building stones, the physical and chemical properties of the stones and their distribution in the United States. The second part, comprising the greater part of the volume (pp. 45–312), takes up in succession the various kinds of rocks and gives an account of the prominent quarries and quarry regions in the successive states arranged alphabetically with brief remarks upon those of abroad. The other parts give the methods of quarrying and dressing stone, the machines employed, a discussion of the effect of weathering, and so on; also appendices presenting in tabular form the physical and chemical characters of the stones in use, prices, etc. The book is well illustrated and the whole forms a more than usual attractive and interesting volume.

9. *Manganese; its uses, ores and deposits;* by R. A. F. PENROSE, Jr. 642 pp., 8vo. Little Rock, 1891, being vol. I of the Annual Report of the Geological Survey of Arkansas for 1890, J. C. Branner, State Geologist.—The subject of manganese has received exhaustive treatment by Dr. Penrose. The volume has a wide scope and covers, first, a discussion of the nature of early uses of manganese; second, the modern uses of manganese; third, the manganese industry in this country and Canada; fourth, a general account of the ores of manganese and fifth,

a detailed description of the manganese deposits of Arkansas, followed by those of other parts of the country. The final chapter deals with the origin, and chemical and geological relations of manganese deposits. An examination of the volume shows that the author has done his work with great thoroughness and the large amount of new matter relative to hitherto little known deposits with the numerous analyses, etc., give the work a high value in addition to that which it has as a convenient digest of what was before known on the subject.

III. Botany.

1. *Botanic Gardens in the Equatorial Belt and in the South Seas.* (Fifth paper.)—In all the gardens hitherto referred to in this series, it is not unusual to meet with plants from different parts of Japan. The southern portions of Japan have contributed plants which thrive, or, at least, can be made to grow even in the warmer gardens of the tropics, while in the hill gardens of the tropics are found certain species from the colder regions of the Empire. It may therefore not be out of place for this series to close with a short sketch of a visit to Japan on my way home. The spring was far enough advanced to give me a glimpse of some of the most interesting vernal species, but not sufficiently so to present the Pæonies, one of the specialties of Japan, at their best.

From Woosung it is a run of less than two days to the straits at Shimonoseki, where the ship enters the Inland Sea. The descriptions of this famous sheet of water do not do justice to its extraordinary picturesqueness. The shores and the water, with their ever changing scenes of interest, keep every passenger attentively employed in forming contrasts between these and similar scenes in other countries. It was worthy of note that travelers who had passed many times over this sea, did not appear to have exhausted their enthusiasm in regard to its beauty in any way. The older travelers were the most eager to point out to the novices the more striking features and combinations.

On the northern shore, we could frequently see the preparations made for extending the railroad, and catch now and then a view of a rigid line of rail contrasting strangely with the general air of the place. There is absolutely nothing which can fairly be called picturesque in or around the railroad stations,—except the people.

The port of Kobe is reached in twenty hours from the southern entrance to the sea. Hyogo, or Hiogo (pronounced by the natives almost as if written Shyogo), lies on the opposite side of the river, Minato-gawa, and is the native part of the double town. Together, the two towns occupy about three miles along the shore and are alike fortunate in having a charming range of hills behind to increase their attractiveness. The tourist loses no time in leaving his ship for the walk or the jinrickisha ride up the

most easily accessible of these hills, and here the native vegetation and cultivated land are on every side. Bright green fields of barley and golden fields of rape-plants appear as if planted solely for decorative purposes, so completely do they adjust themselves to the tone of the landscape. The angular conifers seem far more irregular and picturesque than even the most contorted on our Atlantic coast. It is instructive to correct, or at least check, this impression by a strict comparison of photographs of trees having somewhat similar port. On the Maine coast one can find specimens of *Pinus rigida* and even battered examples of *Pinus Strobus* which are quite as grotesque as any which grow naturally in Japan, but it is out of the question to find in America miles after miles of trees which do not regard the proprieties of growth. And further, in Japan, when by the skillful lopping off of a branch here or there, the grotesque effect can be heightened in a tree near a dwelling, or plainly in sight of one, such artistic pruning is pretty apt to be done.

It may be said once for all that the Japanese give a naturalist to understand that he is heartily welcome to examine their plants to any extent, and even the poorest classes take pleasure in affording such information regarding their plants as may be in their power. All are very lenient in regard to what might strictly be called trespassing on private grounds. Time did not permit me to visit any of the gardens in Kobe, for it was desirable to reach Tokio in the height of the Cherry-blossom season, then so close at hand. Reserving the railroad ride for another occasion, we went by steamer to Yokohama, the principal port of Japan, and did not again arrive in the vicinity of Kobe until some weeks after. By that time the spring transformation was complete. The trees then had much the appearance of ours in the Atlantic states, in June.

Yokohama offers to the botanist some profitable excursions within the treaty limits, where one can travel without a passport. By courtesy, the Japanese government permits foreigners to pass and repass, on certain definite and yet very generous lines. Obedience to local laws, and strict regard to the limitations of the passport, cover all the requirements, for comfortable botanizing or collecting. There are nineteen fixed routes which cover all the more interesting places in the empire, and for each of these routes one passport is demanded. It is obtained on application to the American Consul at any of the treaty ports, who transmits the request to the American Legation at the capital, Tokio, where the American Minister procures the documents from the foreign office. The passport, of which I made use, permitted me to travel from Yokohama to Nikko and vicinity by rail; thence by regular routes to Kozuke, Shinano, Musashi, Sagami, Kai, Suruga, and Totomi to Nagoya, Kioto, and Kobe, with permission to visit Nara, *en route*. This passport was required only at the railway stations and at the hotels and inns, but was not asked for on any walk or short excursion. These facts are mentioned here,

merely to remind intending tourists that no obstacles are now thrown in the way of any one desirous of exploring the Empire. In fact, it may be said, that it is not unusual to find even in out of the way places, people who are anxious to give any assistance in their power in the way of collecting, and of preparing desirable specimens. The means of communication have been so much improved of late years that a tourist can go by rail from Kobe, skirting the base of Fuji, to Yokohama, with great comfort; or he can reach Nikko and the northern port of the lower island with great facility. At any of the points designated in the passport, the tourist can find a convenient center for local exploration.

In Yokohama itself there is no Botanic Garden, but there are good opportunities in and around the city for examining Japanese horticulture. Some of the establishments are large and well organized, and carry a very heavy stock, while some of the smaller ones are interesting on account of their specialties. Few cultivated plants possess more interest than the dwarfed trees found in the larger Japanese Gardens and frequently used as house decorations. The extravagant claims made as to the great age of some of them cannot of course be established by satisfactory evidence, or, for that matter, successfully contested by skeptics. In no case of a potted commercial plant did I hear a greater antiquity claimed than six hundred years; but it is said that in some of the gardens of the nobles, plants much older than this can be found. Dwarfed trees are pointed out in one of the larger gardens in Tokio, which are claimed to go nearly up to the age of a thousand years. After one has carefully examined the very slight growth made each year and has noted the extraordinary painstaking and skill with which every needless bud has been removed, it seems almost ungracious to refuse to accept the unwritten history. The methods by which plants are dwarfed has been clearly explained in many works, and generally with correctness, but a brief mention of the practice in commercial gardens may be useful.

First of all, good subjects for experimenting are selected, and, from the outset, these are placed under favorable conditions for slow development. All buds which can be spared are taken off with great care, and the root-system is brought within as narrow compass as possible. In a few of the cases which were shown me by the nurseryman who gave me instruction, the amount of root-surface retained was ludicrously inadequate to supply the most moderate demands of a healthy plant. And, yet, the plants in question were sufficiently vigorous to present an unfailing crop of bright foliage every year. The buds are reduced in number beyond what one might regard as safe limits for a healthy plant, and thus the dwarfed plant, crippled above and below, becomes almost a pathological specimen. But experience shows abund-

antly, that the few phytomera which are left, are ample to protect the organism against ordinary perils. The prices asked for the best specimens varied from forty to one hundred dollars, (Mexican), these plants being thrifty, clean, picturesque, and very old, say from two to three hundred years. Dwarfed flowering plants, such as cherries, magnolias, and the like, varying from fifteen to fifty years, could be had for about thirty dollars. These prices differ widely in different places, and it is impossible to state any averages.

Larger trees pruned into flat shapes, and encouraged to grow only horizontally, are common, and are among the most interesting specimens of topiary work in the world. The most remarkable one likely to be seen by the tourist is that at Lake Biwa, about ten miles from Kioto. Here at Karasaki, near Otsu, is the immense and very old Pine tree, which is trained horizontally, and extends over a considerable area, with its flat branches supported on pillars and poles. Japanese traditions assign to this tree an exceedingly great age. It should be said in passing, that the practice of training also fruit trees on flat trellises is much in vogue. It imparts to the trees, when one looks down on them from a slight elevation, precisely the impression that they are vines of some sort, grown for shade rather than for fruit. Good examples of this method are to be seen near Yokohama.

At the time of my visit to Tokio, the cherry-blossoms were in perfection. In certain parts of the city and the suburbs the streets were thronged by Japanese who were enjoying the profusion of delicate coloring which clothed the leafless trees. The blossoms most in favor were the pink cherries and the pure white plums. The term "pink," usually and naturally applied to the cherry blossoms of Japan, does them injustice: the tint is rather that of the most delicate "rose-madder." After seeing the blossoms at Uyeno, one cannot wonder that these trees are chosen with which to surround the temples and decorate the approaches to them.

It was my privilege, through the courtesy of Mr. Edwin Dun, Chargé d'Affaires, of the United States, to be present at a reception given by the Emperor and Empress, in one of the Imperial gardens. The cherry-blossoms were here the most interesting horticultural feature; the *Wisterias* were not yet in full bloom, but their very long pendant racemes showed to what a degree of perfection this plant has been brought.

The Botanical Garden in Tokio had just passed out of the charge of Professor Yatabe, well-known to many American botanists, and his successor had hardly yet taken his place. But I was able to make a careful examination of the whole establishment, and received from those in control every attention. Facilities were placed at my disposal for making my short stay as profitable as possible.

The Garden is at a considerable distance from the University, to which it is made tributary for purposes of instruction. It

struck me that there was abundant evidence of a lack of funds for the proper care of the garden: retrenchment has been carried too far in this interesting place. The collection of plants illustrative of systematic botany is large, and many of the specimens well-grown. This seemed to be particularly true of the foreign species. There were excellent examples of trained trees, and in some parts of the grounds, the characteristic landscape gardening had yielded good results. The management of the conifers was especially noticeable.

A small fee is charged for admission to the garden. The grounds are said to be much frequented at certain times. On the occasion of my visit, there were few visitors: this was probably due to the fact that the exhibition of blossoming trees in the vicinity of the temples was far finer in every respect, than that which the garden could present.

A careful search through various horticultural establishments, as well as my study of the Imperial garden at Chokubutsu, has satisfied me that there are many more attractive plants yet to be brought from Japan to our country. Most of them, to be sure, have been already noticed in the horticultural journals, but they have not received the attention which they deserve. Some of the dwarfed flowering shrubs and trees would certainly prove most acceptable for house decoration, while the early flowering trees of large size merit a thorough trial in the middle States of our Union.

Answering a question which has been often asked, it will be well to mention the ease and rapidity with which a tourist can visit the famous locality, Nikko. Of the temples there it is not necessary to speak, but the groves of conifers which surround them must be alluded to. These are of great size and of symmetrical port. Many of them are arranged effectively in and around the temple grounds, but those which are of highest interest are the magnificent specimens which constitute the miles upon miles of shaded avenues. This locality which formerly required a long and tedious jinrickisha ride, can now be reached in less than a day's journey from Tokio. In closing, it must be confessed that the new railroads in Japan, which it may well be claimed have destroyed much of the peculiar charm of the Empire, have rendered accessible to many naturalists, localities which otherwise they could not have found time to study.

In bringing to an end this short series of sketches of a long journey, I must be pardoned for calling attention again to the extraordinary fact that the newly settled countries of the South Seas and the newly awakened people of the Orient have hastened to provide themselves with appliances for research and instruction in Natural History on a scale which should put to blush some of our communities. There is, as we have seen in earlier numbers of this series, hardly a large town in Australasia which does not possess a good Botanic Garden or a Natural History Museum, or both. Even in places which do not have a Botanic

Garden, properly so-called, there is, as in Dunedin, in New Zealand, and Geelong, in Victoria, a public garden, in which a good deal of attention is given to the exhibition of native plants.

Can there be any valid excuse urged by the young and flourishing cities of our own country for not providing for the public, these simple and useful means for popular instruction?

To serve as a basis for comparison with our own communities, it is thought best to subjoin a few statistics relative to population taken from Hübner's Statistische Tabellen. The figures apply to the towns and cities of which mention has been made in the sketches.

Melbourne and suburbs	410,000
Sydney	357,000
Adelaide	128,000
Auckland	57,000
Dunedin	46,000
Christchurch	45,000
Brisbane	74,000
Wellington	28,000
Hobart	25,000
Geelong	21,000

These figures, which are only approximate, correspond very nearly to those given in the latest Australian Year-Book (1890) accessible to me. Hübner's data are preferred, because the year-book does not add in the population of the suburbs of some of the cities. In fairness, these should be included.

It would seem that many of our American cities and towns have much to learn from these smaller communities in the islands of the South Seas. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Analysis of the water of the Salt Lake, Aliapaakai, on Oahu, Hawaiian Islands;* by Prof. Lyons of Oahu College (Daily Pacific Comm. Advertiser of Oahu, Oct. 8, 1891).—The salt lake of Oahu is situated near the sea-level, on the south side of the island, in a basin made of a combination of shallow craters of basaltic tufa. It is described by J. D. Dana in his Expedition Report, p. 245, and his work on Volcanoes, p. 297. Its position may be seen on the map of Oahu, Plate IV of volume xxxvii (1889) of this Journal. In dry seasons the bottom of the lake is covered with a deposit of crystallized salt. The water is saturated brine, yet it differs much in composition from the brine obtained by evaporating to saturation ordinary sea-water. The difference is strikingly shown on mixing the two clear fluids, when a copious deposit immediately forms of sulphate of lime, so that the mixture almost solidifies. The specific gravity of the water, even at a temperature of 80° F. is 1,256. The water of the Dead Sea is considerably lighter, its specific gravity having been found by

different observers to range from 1·13 to 1·24. The results of the analysis are given below, together with comparative figures showing the composition (average of several analyses) of the water of the Dead Sea and that of concentrated sea water from Kakaako salt works. The figures represent in each case the quantity in grains of the ingredient contained in one wine gallon of the water :

	Salt Lake. Grains.	Dead Sea. Grains.	Concentrated Sea Water. Grains.
Chloride of sodium	6,989	5,137	13,239
Chloride of calcium	7,742	2,077	absent
Chloride of magnesium	7,790	8,235	3,779
Bromide of magnesium	99	208	57
Sulphate of magnesium	absent	absent	2,478
Sulphate of calcium	34	58	22
Chloride of potassium	156	736	534
Total solids	22,810	16,451	20,109
Weight of one gallon (approximate)	73,044	68,900	72,180

The most remarkable peculiarity of the water is the excessive quantity of calcium chloride, the large amount of magnesium chloride and the absence of magnesium sulphate. Part of the lime as well as the magnesia may have been supplied by the tufa ; but there is a ledge of coral-reef rock on one side.

2. *National Academy of Sciences.*—The following is a list of papers accepted for reading at the meeting of the Academy held at New York, Nov. 10–12 :

G. L. GOODALE: Some aspects of Australian vegetation. The nomenclature of vegetable histology.

C. S. HASTINGS: Certain new methods and results in optics.

T. C. MENDENHALL: Exhibition of the new pendulum apparatus of the U. S. Coast and Geodetic Survey, with some results of its use. The use of a free pendulum as a time standard

E. D. COPE: Degenerate types of scapula and pelvic arches in the Lacertilia.

T. B. OSBORNE: The proteids or albuminoids of the oat-kernel—second paper.

C. S. PEIRCE: Astronomical methods of determining the curvature of space.

J. A. ALLEN: Geographical variation among North American birds, considered in relation to the peculiar intergradation of *Colaptes Auratus* and *C. Cafer.*

S. C. CHANDLER: The variation of latitude.

S. H. SCUDDER: The Tertiary Rhynchitidæ of the United States.

O. N. ROOD: A color system.

J. K. REES: Preliminary notice of the reduction of Rutherfurd's photographs.

H. A. ROWLAND: The application of spectrum analysis to the analysis of the rare earths, and a new method for the preparation of pure yttrium.

THEO. GILL: A nomenclator of the families of fishes.

A. A. MICHELSON: Measurement of Jupiter's satellites by interference.

W. K. BROOKS: The follicle cells of Salpa.

3. *The Metal Worker:* Essays on House Heating by steam, hot water and hot air with introduction and tabular comparisons. Arranged for publication by A. O. KITTREDGE. New York. 288 pp. 8vo. 1891 (David Williams).—This volume contains a number of essays by a variety of writers called out by a series of prize competitions established by "The Metal Worker"

in 1888. They discuss, from a thoroughly practical standpoint, the various forms of heating in use with illustrations, tabular statements of cost and so on and thus give the reader a wide range of information on a subject of prime importance.

The Four Rocks, with Walks and Drives about New Haven; by James D. Dana. 120 pp. 8vo, with 7 plates. New Haven, Sept. 1891. (E. P. Judd)—This little book contains the author's paper in the early part of this volume, and also eighty pages of instructions, geological notes, etc., with regard to walks and drives within twenty miles of New Haven.

Copernic et la découverte du Système du Monde, par Camille Flammarion. 250 pp. 12mo. Paris (Marpon et Flammarion).

Systematic list of the British Oligocene Eocene Mollusca of the F. E. Edwards Collection in the British Museum, by R. B. Newton, F.G.S. 366 pp. 8vo. London, 1891.

Transactions of the Kansas Academy of Science, vol. xii 1889–90. Topeka, 1890.—Prof. S. W. Williston gives figures of the complete skull and a cervical vertebra of his new Cretaceous Plesiosaur (Cimoliosaurus Snowii) from the Niobrara Cretaceous of Western Kansas, on pp. 174, 176.

Stratigraphy of the Bituminous Coal Field of Pennsylvania and West Virginia by I. C. White. 212 pp. 8vo, with a map and sections. U. S. Geol. Survey Bulletin. No 65, Washington, 1891.

The Mediterranean Naturalist, a monthly Journal of Natural Science, edited by J. H. Cooke, F.G.S., at Malta.—No. 1 of this monthly of 12 to 16 pages was issued June 1, 1891. Price 5 shillings a year. Address, the editor at the Lyceum, Malta. In number 2, a paper on the geology of the Malta Islands by the editor is commenced.

Progress Report on Irrigation in the United States, under the direction of the Secretary of Agriculture; Artesian underflow and Irrigation Investigation, Part I by R. J. Hinton. 338 pp. 8vo; Part II, with maps and profiles, by E. S. Nettleton, Chief Engineer of the Investigation. Washington, 1891.

OBITUARY.

J. Francis Williams, Assistant Professor of Geology and Mineralogy in Cornell University, died at Ithaca, N. Y., on November 8th, of malarial fever. He was but twenty-nine years of age, but had already done some excellent scientific work and his life, thus prematurely closed, gave promise of being highly useful and successful. For the past year he had been a teacher at Clark University in Worcester, Mass., and under the direction of the University he had spent considerable time in the survey of Arkansas, collecting materials for a report on the petrography of the State, which is now ready for publication. Articles by him upon some Arkansas minerals have been published in the numbers of this Journal for December, 1890, and July, 1891. At the time of his death he had hardly more than entered upon his new duties at Cornell, but his loss is deeply felt there, as well as in circles where he was better known.

INDEX TO VOLUME XLII.*

A

Academy, National, meeting at New York, 523.
Aerodynamics, experiments in, Langley, 427.
Alabama, geological survey, 515.
Alaska, expedition to, Russell, 171.
American Geological Society, Washington meeting, 77.
Arkansas, geol. report, Branner, 347.
Association, American, president's address, 271.
  Washington meeting, 353.
  British, 358.

B

Bailey, E. H. S., Tonganoxie meteorite, 385.
Baker, E. P., volcano of Kilauea, 77.
Barker, G. F., chemical abstracts, 66, 169, 256, 339, 422, 509.
Barometer, mercurial, Waggener, 387.
Barus, C., continuity of solid and liquid, 125; contraction of molten rock, 498; solution of vulcanized india rubber, 359.
Beecher, C. E., development of Bilobites, 51.
Bibliotheca Zoologica, Taschenberg, 438.
Bigelow, F. H., solar corona, 1; causes of variations of the magnetic needle, 253.
Blair, Chemical analysis of iron, 428.
Botany—
  Annual plants, vitality, Holm, 304.
  Botanic gardens in the equatorial belt and South seas, Goodale, 173, 260, 347, 434, 517.
  Botany, economic possibilities of, Goodale, 271.
Brackett, R. N., newtonite and rectorite, 11.
Branner, geol. report of Arkansas, 347.

C

Call, R. E., silicified woods of eastern Arkansas, 394.
Cape Cod, sea-encroachment at, Marindin, 172.
Cary, A., geological facts on Grand river, Labrador, 419, 516.
Chemistry, Dictionary of applied, Thorpe, 341.
  Inorganic, system of, Ramsay, 510.
  Organic, Richter, 509.
Chemistry—
  Alkaloid from Conium maculatum, Ladenburg and Adam, 423.
  Allotropic silver, Lea, 312.
  Aluminum, electro-metallurgy, Minet, 67.
  Antimony, determination, Gooch and Gruener, 213.
    and arsenic separated, Gooch and Danner, 308.
  Battery, secondary, chemistry of, Cantor, 169.
  Black sulphur of Magnus, Knapp, 422.
  Boron tri-iodide, Moissan, 256.
  Carbon compounds, chemistry of, von Richter, 509.
    monoxide, action of heat on, Berthelot, 67; new reaction, 170.
  Chemical and electrical energy in voltaic cells, Levay, 66.
    reactions, dead space in, Liebreich, 170.
  Chlorates, estimation, Gooch and Smith, 220.
  Hydrazine hydrate, Curtius and Schulz, 257.
  Indigo-carmine, synthesis of, Heymann, 257.
  Iron- and nickel-tetracarbonyl, Mond and Quincke, 424.
  Mercury, detection in cases of poisoning, Lecco, 68.
  Oxygen, spectrum of liquid, Olszewski, 338.
  Ozone produced by rapid combustion, Ilosvay, 339.
  Potassium determined spectroscopically, Gooch and Hart, 448.
  Silicon, new form, Warren, 423.
  Sulphur, new modifications, Engel, 509.
  Sulphuryl peroxide, Traube, 340.
  Tartaric acid, sensitive reaction for, Mohler, 425.
  Tetrazotic acid and derivatives, Lossen, 68.
  Titanic acid in soils, Dunnington, 491.
Clarke, F. W., constitution of certain micas, vermiculites and chlorites, 242.

* This Index contains the general heads Botany, Chemistry, Geology, Minerals, Obituary, and under each the titles of Articles referring thereto are mentioned.

Color photography, see *photography*.
Comets, capture of, by planets, Newton, 183, 482.
Comstock, G. C., secular variation of latitudes, 470.
Corona, solar, Bigelow, 1.
Crosby, W. G., composition of till or bowlder clay, 259.
Cutter, E, phonics of auditoriums, 468.

D

Dale, T. W., the Greylock synclinorium, 347.
Dana, J. D., non-volcanic igneous ejections and the Four Rocks of New Haven, 79; Percival's map of the trap-belts of central Connecticut, and the upturning of the sandstone, 439.
Danner, E. W., separation of antimony from arsenic, 308.
Davis, W. M., fossiliferous black shale of Connecticut, 72.
Davison, C., earthquakes in Great Britain in 1889, 512.
Davison, J. M., kamacite, tænite and plessite, analyses, 64.
Dawson, G. M., geology of the Rocky Mountain region in Canada, 259.
Denning, W. F., Telescopic work for starlight evenings, 178.
Denudation in the Egyptian desert, Walther, 177.
Ditt. A., Leçons sur les Métaux, 258.
Dumble, E. T., geol. survey of Texas, 430.
Dunnington, F. P., titanic acid in soils, etc., 491.

E

Eakins, L. G., astrophyllite and tscheffkinite, 34.
Earthquakes in Great Britain, 1889, Davison, 512.
Edwards, A. M., infusorial earths of the Pacific coast, 369.
Egleston, T., Catalogue of minerals and synonyms, 434.
Electrical oscillations, damping of, Bjerknes, 511.
on iron wires, Trowbridge, 223.
waves, velocity, Avons and Rubens, 511.
Electricity, chapters on, Sheldon, 511.
discharge through exhausted tubes, Thomson, 426.
and magnetism, mathematical theory, Emtage, 510.
Electrochemical equivalent of copper, Vanni, 511.
Electrolytic generation of gas, Chabry, 511.
Electromagnetic units, ratio of to electrostatic, Thomson and Searle, 427.
Electrometers, small, Boys, 342.
Emtage, W. T. H., Mathematical theory of electricity and magnetism, 510.

F

Ferrier, W. F., tungsten minerals in Canada, 347.
Flying machine, Maxim's, 342.
Foote, A. E, meteoric iron of Cañon Diablo, 413.
Foshay, P. M., glacier scratches in western Pennsylvania, 172.
Fossil, see *Geology*.
Frazer, R., Tables for the determination of minerals, 77.
Fremy, E., Synthese du Rubis, 432.

G

Gas, electrolytic generation of, Chabry, 511.
Geikie, A., history of volcanic action in the British Isles, 178.
Geological annual, 1889, Carez and Douvillé, 76.
Geological Reports and Surveys—
Alabama, Smith, 515.
Arkansas, 1888, Branner, 347.
Georgia, 1890, 1891, 515.
Missouri, Bulletin, No. 5, 515.
New Jersey, 1890, Smock, 70.
Texas, Dumble, 430.
Geological Society of America, meeting at Washington, 77, 344.
Geologists, international congress, meeting at Washington, 78, 343
U. S. Association of Government, 344.
Geology—
Archæan limestone of N. Jersey, 70.
rocks of Missouri, origin of, Haworth, 515.
Asphaltum of Utah and Colorado, Stone, 148.
Bilobites, development of, Beecher, 51.
Cambrian, lower, fauna of, Walcott, 345.
St. John group, No. 2, fauna of, Matthew, 73.
rock-disintegration as related to transitional crystalline schists, Pumpelly, 346.
Carboniferous in France, flora of, Zeiller, 75.
Contact-metamorphism, formation of graphite in, 514.
Fossil insects of the world, index to known, Scudder, 516.
Glacial Lake Agassiz in Manitoba, Upham, 429.

GEOLOGY—
Glacier clays and till near Boston, Crosby, 259.
scratches in Pennsylvania, Foshay and Hice, 172.
Grand River, Labrador, Cary, 419, 516.
Greenstone schist in Michigan, Williams, 259.
Greylock synclinorium, Dale, 347.
Iron-ores, genesis, Kimball, 231.
Jura-Trias, see *Triassic*.
Mount St. Elias, Russell, 171.
Ouachita Mt. system, Hill, 111.
Peridotite dikes near Ithaca, N. Y., Kemp, 410.
Permian coal plants, Zeiller, 75.
Pleistocene fluvial planes of Pennsylvania, Leverett, 200.
Rocky Mt. region in Canada, Dawson, 259.
Silurian sandstone of Keweenaw Pt., Wadsworth, 170.
Sphenophyllum, Newberry, 76.
Spherulites in rhyolite, Iddings and Penfield, 39.
Steep Rock Lake, Ont., geology, Smyth, 317.
Stegosaurus, restoration of, Marsh, 179.
Tertiary, pre-pleistocene age of the orange sands, Salisbury, 252.
silicified wood of Arkansas, Call, 394.
Trap range of the Keweenawan series, Wadsworth, 417.
Triassic fossiliferous black shale of Connecticut, Davis and Loper, 72.
trap rocks of Connecticut, Davis and Loper, 72.
of New Haven, Dana, 79.
Percival's map of, and on the mountain-making, Dana, 439.
Vertebrate fossils as a criterion of age, Marsh, 336.
Volcanic, see *Volcanic*.
Water of a salt lake on Oahu, anal., 522.

Georgia, geological survey for 1890, 1891, 515.
Glacier, see *Geology*.
Gooch, F. A., determination of antimony, 213; the determination of potassium spectroscopically, 448; estimation of chlorates, 220; separation of antimony from arsenic, 308.
Goodale, G. L., botanic gardens in the equatorial belt and south seas, 173, 260, 347, 434, 517; possibilities of economic botany, 271.
Gruener, H. W., determination of antimony, 213.

H

Hale, G. E., photographic investigation of solar prominences, 160; the ultra-violet spectrum of the solar prominences, 459.
Harrington, J. B., so-called amber of Cedar Lake, Canada, 332.
Hart, T. S., potassium determined and detected spectroscopically, 448.
Hawaiian Islands, salt lake of Oahu, 522.
volcano of Kilauea, 77.
Haworth, E., origin of Archean rocks of Missouri, 515.
Hice, R. R., glacier scratches in western Pennsylvania, 172.
Hidden, W. E., new yttrium-silicate, rowlandite, 430.
Hill, R. T., Ouachita Mt. system, 111.
Hillebrand, W. F., new analyses of uraninite, 390.
Hoffman, G. C., ilvaite, 432.
Holm, T., vitality of some annual plants, 304.

I

Iddings, J. P., spherulites from Wyoming, 39.
India rubber, solution of, Barus, 359.
Indian Territory, geology, Hill, 111.
Interference of light, influence of brightness upon, Ebert, 342.
Infusorial earths of the Pacific coast, Edwards, 369.
Iron, Chemical analysis, Blair, 428.

K

Keller, H. F., Michigan minerals, 499.
Kemp, J. F., peridotite dikes near Ithaca, N. Y., 410.
Kilauea, volcano of, Baker, 77.
Kimball, J. P., genesis of iron ores, 231.
Kittredge, The Metal Worker, 523.
Kokscharow, N. v., Mineralogie Russlands, 77.

L

Labrador, geological notes on, Cary, 419, 516.
Lane, A. C., Michigan minerals, 499.
Langley, S. P., experiments in aerodynamics, 427.
Latitudes, secular variation of, Comstock, 470.
Lea, M. C., allotropic silver, 312.
Leidy memorial museum, 438.
Leverett, F., pleistocene fluvial planes of Pennsylvania, 200.
Light, reflection and refraction by their surface layers, Drude, 70.
Luedeking, C., Missouri barite, 495.
Lyons, A. B., analysis of water from the salt lake of Oahu, 522.

M

Magnetic declination in the U. S. for 1890, Schott, 178.
needle, causes of variations, Bigelow, 253.
Manganese ores in Arkansas, Penrose, 516.
Marindin, H. L., losses of Cape Cod by sea-encroachments, 172.
Marsh, O. C., restoration of Stegosaurus, 179; new vertebrate fossils, 265; geological horizons determined by vertebrate fossils, 336.
Matthew, G. F., fauna of the St. John group, 73.
Maxim's flying machine, 342.
Merrill, G. P., stones for building and decoration, 516
Meteoric iron, analyses, Davison, 64.
Cañon Diablo, Foote, 413.
Tonganoxie, Bailey, 385.
Metal Worker, Kittredge, 523.
Mineralogie Russlands, Kokscharow, 77.
Minerals, catalogue, English, 438.
and synonyms, catalogue of, Egleston, 434.
Tables for the determination of, Frazer, 77.
MINERALS—
Amber, Cedar Lake, Canada, 332. Anatase, see *octahedrite*. Antlerite, Colorado, 434. Astrophyllite, Colorado, 34.
Barite, Missouri, 495. Bernardinite, California, 46. Biotite, N. C., 242. Brandtite, Sweden, 433.
Cassiterite, Mexico, 407. Cerussite, Arizona, 405. Chemawinite, Cedar Lake, Canada, 332. Chloritoid, Michigan, 499.
Ganophyllite, Sweden, 433. Gmelinite, Nova Scotia, 57. Graphite, formed in contact-metamorphism, 514. Grünerite, Michigan, 505. Gypsum, Girgenti, 407.
Hallite, Penn., 244. Hematite, Mexico, 407.
Ilvaite, Canada, 432. Iron, meteoric, 64.
Kallilite, Prussia, 433. Kamacite, 64. Kaolinite, Arkansas, 17.
Mordenite, axial ratio, 409. Muscovite, Maine, 251.
Newtonite, Arkansas, 13.
Octahedrite, Buckingham Co., Va., 431. Offrétite, France, 433. Orpiment, Yellowstone, 403.
Painterite, Penn., 247. Pennine, Texas, Pa., 408. Plessite, 64. Plumboferrite, Sweden, 434. Protovermiculite, Ark., 242. Pyrophanite, Sweden, 433.
Quartz crystals in spherulites, 42.
Realgar, Yellowstone, 403. Rectorite, Ark., 16. Riebeckite, Michigan, 508. Rowlandite, Texas, 430. Rubies, synthesis, Fremy, 432.
Sulphur, Yellowstone, 401. Sychnodymite, Prussia, 433.
Tænite, 64. Tscheffkinite, Virginia, 36. Tungsten minerals in Canada, 347.
Umangite, Argentine Republic, 433. Uraninite, new analyses, 390.
Missouri, geological survey, bulletin No. 5, 515.
Molten rock, contraction, Barus, 498.
Mount St. Elias, expedition to, Russell, 171.

N

Newberry, J. S., genus sphenophyllum, 76.
New Jersey, geological report, 1890, 70.
Newton, H. A., capture of comets by planets, 183, 482.

O

OBITUARY—
Ferrell, W., 358.
Joy, C. A., 78.
Williams, J. F., 524.
Organic dyes, optical relations of, Vogel, 342.
Organ pipes, energy used in, Wead, 21.
Ostwald's Klassiker der Exacten Wissenschaften, 178.

P

Peloponnesus, geology of, Philippson, 173.
Penfield, S. L., minerals in spherulites of rhyolite, 39.
Penrose, R. A. F., manganese ores in Arkansas, 516.
Philippson, A., geology of the Peloponnesus, 173.
Phonics of auditoriums, Cutter, 468.
Phosphorescence, Wiedemann, 69.
Photography of the spectrum in color, Vogel, 426.
in color, Thwing, 388.
Physical observatory, Washington, 78.
Pirsson, L. V., gmelinite, 57; mineralogical notes, 405; sulphur, orpiment and realgar in the Yellowstone, 401.
Polar light and cosmic dust, Liveing and Dewar, 69.
Pumpelly, R., secular rock-disintegration as related to transitional crystalline schists, 346.

R

Ramsay, W., System of inorganic chemistry, 510.
Richter, V. von, Chemistry of carbon compounds, 509.
Rotation, measurement of, Prytz, 341.
Russell, I. C., expedition to Mt. St. Elias, 1890, 171.

S

Salisbury, R. D., age of the orange sands, 252.
Schneider, E. A., constitution of certain micas, vermiculites and chlorites, 242.
Schott, C. A., magnetic declination in the United States, 178.
Scudder, S. H., Index to known fossil insects of the world, 516.
Sharpless, F. F., Michigan minerals, 499.
Sheldon, S., chapters on electricity, 511.
Silver, allotropic, Lea, 312.
Sinter, siliceous, gold-bearing, Weed, 166.
Smith, C. G., estimation of chlorates, 220.
Smyth, H. L., geology of Steep Rock Lake, Ontario, 317.
Specific heat determined by electric current, Pfaundler, 341.
Spectra, solar, photographic investigation, Hale, 160.
Spectrum of liquid oxygen, absorption, Olszewski, 338.
ultra-violet of the solar prominences, Hale, 160, 459.
Solar corona, Bigelow, 1.
prominences, photographic investigation of, Hale, 160, 459.
Solid and liquid, continuity of, Barus, 125.
Sound, intensity of, Wead, 21.
Stanley-Brown, J., bernardinite, a mineral or a fungus?, 46.
Stegosaurus, restoration of, Marsh, 179.
Stone, G. H., asphaltum of Utah and Colorado, 148.
Stones for building and decoration, Merrill, 516.

T

Telescopic work for starlight evenings, Denning, 178.
Texas, geol. survey, Dumble, 430.
Thorpe, T. E., Dictionary of applied chemistry, 341.
Thought transference, Lodge, 343.
Thwing, C. B., color photography by Lippman's process, 388.
Trowbridge, J., dampening of electric oscillations on iron wires, 223; physical abstracts, 69, 341, 426, 511.

U

Upham, W., exploration of the glacial Lake Agassiz in Manitoba, 429.

V

Vertebrate fossils, Marsh, 265, 336.
Volcanic action in the British Isles, history of, Geikie, 178.
Volcano Kilauea, Baker, 77.

W

Wadsworth, M. E., relations of the eastern sandstone of Keweenaw Point to the Lower Silurian limestone, 170; trap range of the Keweenawan series, 417.
Waggener, W. J., mercurial barometer, 387.
Walcott, C. D., fauna of the lower Cambrian, 345.
Walther, J., die Denudation in der Wüste, etc, 177.
Water, expansion of, Marek, 427.
of the salt lake of Oahu, 522.
Wave, explosive, in solid and liquid bodies, Berthelot, 66.
Wead, C. K., intensity of sound, 21.
Weed, W. H., gold-bearing hot spring deposit, 166; sulphur, orpiment and realgar in the Yellowstone, 401.
Wheeler, H. A., Missouri barite, 495.
Williams, G. H., anatase from Buckingham Co., Va., 431; greenstone schist areas of Michigan, 259.
Williams, J. F., newtonite and rectorite, 11.

Z

Zeiller, R., fossil flora of French Carboniferous, 75,

LITTELL'S LIVING AGE.

As THE LIVING AGE approaches its jubilee, it is interesting to recall the prophecy made concerning it by MR. JUSTICE STORY upon reading the prospectus in April, 1844. He then said, "I entirely approve the plan. If it can obtain the public patronage long enough, it will contribute in an eminent degree to give a healthy tone, not only to our literature, but to public opinion. It will enable us to possess in a moderate compass a select library of the best productions of the age."

That THE LIVING AGE has fully justified this forecast is proved by the constant praises which, during all the years of its publication, have been bestowed upon it by the press; some of the more recent of which are given below.

A WEEKLY MAGAZINE of sixty-four pages, THE LIVING AGE gives more than

Three and a Quarter Thousand

double-column octavo pages of reading-matter yearly, forming four large volumes. It presents in an inexpensive form, considering its great amount of matter, with freshness, owing to its weekly issue, and with a satisfactory completeness attempted by no other publication,

The best Essays, Reviews, Criticisms, Tales, Sketches of Travel and Discovery, Poetry, Scientific, Biographical, Historical, and Political Information, from the entire body of Foreign Periodical Literature.

It is therefore invaluable to every American reader, as the only satisfactorily fresh and COMPLETE compilation of an indispensable current literature, — indispensable because it embraces the productions of THE ABLEST LIVING WRITERS in all branches of Literature, Science, Politics, and Art.

Opinions.

"If a cultured stranger from another world were to find himself in this one, and were to make a study of our literary advantages, he would be impressed especially, we are confident, by the abundance, variety and high average quality of the contents of LITTELL'S LIVING AGE."— *The Congregationalist, Boston.*

"It is nearly half a century since the first volume of this sterling publication came from the press, and to-day it stands the most perfect publication of its kind in the world. . There is but one LIVING AGE, though many have essayed imitations. While their intent has no doubt been worthy, they have lacked that rare discriminating judgment, that fineness of acumen, and that keen appreciation of what constitutes true excellence, which make LITTELL'S LIVING AGE the incomparable publication that it is. . We know of no other publication that is so thorough an educator, for it touches all live subjects and gives the best thought of leading minds concerning them."— *Christian at Work, New York.*

"No eclectic journal has ever deserved so well of the public. . It contains nearly all the good literature of the time."— *The Churchman, New York.*

"It improves with age. It is a treasure-house of the best periodical literature in the language, and subscribers are easily enabled to keep themselves acquainted with the work of the most eminent writers of the time."— *Standard of the Cross, Philadelphia.*

"It maintains its leading position in spite of the multitude of aspirants for public favor. . He who subscribes for a few years to it gathers a choice library, even though he may have no other books."— *New-York Observer.*

"Indeed it may well be doubted whether there exists any more essential aid to cultivation of the mind among English-speaking people; and its importance increases with the ever-growing rush and hurry of modern times. . Certain it is that no other magazine can take its place in enabling the busy reader to keep up with current literature."— *Episcopal Recorder, Philadelphia.*

"It has, in the half century of its existence, furnished its host of readers with literature the best of the day, such as cannot fail to educate and stimulate the intellectual faculties, and create tastes and desires for loftier attainments."— *Presb'n Banner, Pittsburgh.*

"It is incomparably the finest literary production of modern times."— *Herald and Presbyter, Cincinnati.*

"For the man who tries to be truly conversant with the very best literature of this and other countries, it is indispensable."— *Central Baptist, St. Louis.*

"The subscription price is low for the abundance of excellent reading given."— *New-York Evangelist.*

"It would be cheap at almost any price."— *California Christian Advocate, San Francisco.*

"It saves much labor to a busy man who only wants to read the best."— *The Advance, Chicago.*

"It retains the characteristics of breadth, catholicity and good taste which have always marked its editing. The fields of fiction, biography, travel, science, poetry, criticism, and social and religious discussion all come within its domain and all are well represented."— *Boston Journal.*

"It may be truthfully and cordially said that it never offers a dry or valueless page."— *New-York Tribune.*

"To read it is itself an education in the course of modern thought and literature."— *Buffalo Commercial Advertiser.*

"Coming weekly, it has a great advantage over the monthly magazines and reviews."— *San-Francisco Chronicle.*

"It is one of the invaluables to those whose time is limited."— *Houston (Tex.) Post.*

"No one who pretends to keep *an courant* with what is doing in science and literature can afford to dispense with it."— *Hartford Courant.*

"In giving a comprehensive view of the best current literature, the product of the best writers of the day, it stands unrivalled."— *Canada Presbyterian, Toronto.*

PUBLISHED WEEKLY at $8.00 a year, free of postage.

☞ **TO NEW SUBSCRIBERS for the year 1892,** remitting before Jan. 1, the weekly numbers of 1891 issued after the receipt of their subscriptions, will be sent *gratis.*

CLUB PRICES FOR THE BEST HOME AND FOREIGN LITERATURE.

["Possessed of LITTELL'S LIVING AGE, and of one or other of our vivacious American monthlies, a subscriber will find himself *in command of the whole situation.*"— *Philadelphia Evening Bulletin.*]

For $10.50, THE LIVING AGE and any one of the *four-dollar* monthly magazines (or *Harper's Weekly* or *Bazar*) will be sent for a year, postpaid; or, for $9.50, THE LIVING AGE and *Scribner's Magazine,* or *Lippincott's Magazine,* or the *St. Nicholas.*

Rates for clubbing THE LIVING AGE with more than one other periodical will be sent on application. Sample copies of THE LIVING AGE 15 cents each.

ADDRESS **LITTELL & CO., 31 Bedford St., Boston.**

CONTENTS.

Page

ART. XLVII.—Percival's map of the Jura Trias trap-belts of Central Connecticut, with observations on the upturning, or mountain-making disturbance, of the Formation; by J. D. DANA. With a map, Plate XVI..... 439

XLVIII.—The Detection and Determination of Potassium Spectroscopically; by F. A. GOOCH and T. S. HART... 448

XLIX.—The Ultra-Violet Spectrum of the Solar Prominences; by G. E. HALE..... 459

L.—Phonics of Auditoriums; by E. CUTTER 468

LI.—The Secular Variation of Latitudes; by G. C. COMSTOCK 470

LII.—Capture of Comets by Planets, especially their Capture by Jupiter; by H. A. NEWTON 482

LIII.—Distribution of Titanic Oxide upon the surface of the Earth; by F. P. DUNNINGTON 491

LIV.—Notes on a Missouri Barite; by C. LUEDEKING and H. A. WHEELER 495

LV.—The Contraction of Molten Rock; by C. BARUS 498

LVI.—Notes on Michigan Minerals; by A. C. LANE, H. F. KELLER and F. F. SHARPLESS 499

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Two new Modifications of Sulphur, ENGEL: Chemistry of the Carbon compounds or Organic Chemistry, VON RICHTER, 509.—System of Inorganic Chemistry, Wm. RAMSAY: An Introduction to the Mathematical Theory of Electricity and Magnetism, W. T. H. EMTAGE, 510.—Chapters on Electricity, S. SHELDON: Apparent change in electrochemical equivalent of copper. VANNI: Electrolytic generation of Gas in a closed space, CHABRY: Damping of electrical oscillations, BJERKNES: Velocity of Electrical waves in solid insulators, AVONS and RUBENS, 511.

Geology—British Earthquakes of 1889, C. DAVISON, 512.—Formation of Graphite in Contact-metamorphism, BECK and LUZI, 514.—Geological Survey of Alabama, E. A. SMITH: Geological Survey of Missouri, Bulletin No. 5, A. WINSLOW: Geological Survey of Georgia, L. W. SPENCER, 515.—Geological facts on Grand River, Labrador, A. CARY: Index to the known Fossil Insects of the World, S. H. SCUDDER: Stones for Building and Decoration, G. P. MERRILL: Manganese, its uses, ores and deposits, R. A. F. PENROSE, Jr., 516.

Botany—Botanic Gardens in the Equatorial Belt and in the South Seas, 517.

Miscellaneous Scientific Intelligence—Analysis of the water of the Salt Lake, Aliapaakai, on Oahu, Hawaiian Islands, Prof. LYONS, 522.—National Academy of Sciences: The Metal Worker, A. O. KITTREDGE, 523.

Obituary—J. FRANCIS WILLIAMS.

Page

439

448

459

468

470

482

491

495

498

499

istry
m of
The-
Elec-
pper,
g of
tors,

hite
ama,
ow:
rand
orld,
nga-

lia-
of